Final Report
Easel 5000

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ABSTRACT

Easel 5000 is a project aimed at designing an adjustable art easel for an artist having motor function disorders that affect strength, dexterity and range of motion. The needs of the artist require the easel to be easily adjustable, have a large range of motion with locking positions and have the ability to integrate with a pre-existing wheel chair tray. Additional features of the project include an LED lighting unit with adjustable light intensity, and a canvas holder that accommodates a large range of canvases.

1 INTRODUCTION

1.1 Background

Project Easel 5000 is a cooperative effort between UConn's Biomedical Engineering Senior design class and the National Science foundation. The specific project being worked on for the National Science foundation is Engineering Projects to Aid Persons with Disabilities. The mission of this program is to create devices that assist individuals in reaching their maximum potential for enjoyable and productive lives Dr. Brooke Hallowell will be the National Science Foundation representative consulting on project Easel 5000. The project is being done for an artist at Passion Works Studios. Passion Works is a unique program that creates art opportunities for people with developmental disabilities. Patty Mitchell, the art director at Passion Works studios, was the main contact for the project Tom Depugh is the artist the project is being completed for and his disability is cerebral palsy. Cerebral palsy is a condition that results from brain damage. The symptoms include loss of fine motor ability, abnormal muscle tone, abnormal muscle movements, and vision problems. The ultimate goal of the project is to build an art easel that will allow Tom to paint from his wheel chair.

1.2 Purpose of Project

Because cerebral palsy affects one's strength, dexterity and range of motion, the easel will be built to compensate the artist in these areas. Previously, an adjustable easel was designed in 2003, but did not completely fulfill the needs of the artist. The first design did not have the adjustability needed by Tom. It also had a motor that was difficult to use, and was a t hazard because of the motors exposed electrical cords. The ultimate goal of the current project, Easel 5000, is to create a new design better suited to meet the needs of the artist and address the design flaws of the first easel.

The artist is in need of an easel that can be easily adjusted. Since the artist has a limited range of motion, painting with a single position easel is incredibly difficult. The artist also cannot use a standard easel with tripod legs due to the fact that he is in a wheelchair. The easel would need to account for wheelchair dimensions in order for the artist to use it appropriately. In addition, the artist is unable to paint unless the canvas projects out close to his wheel chair.

Artist Tom Depugh

With this project we aim to use educational knowledge and background to design an easel that meets the specifications presented by the National Science Foundation. These specifications fall into four main categories environmental, electrical, mechanical, and economical. The environment the easel will be used in will require it to portable, wheel chair tray size and easily used in a busy art room setting. The electrical requirements will include a cordless light source with an easy on/off switch. Mechanically the easel will need stability, flexible locking joints, and be able to accommodate a 20' X 20' canvas. Economically the design and construction of the easel must cost less than $750. The project is also meant to be an introduction to industry experience. Learning how to develop, organize, and design a project as well as team work are all important aspects of the project.

1.3 Previous Work Done by Others

1.3.1 Marketed Products-There are many products out in the market with similar designs as the Easel 5000. These products range in price drastically and have varying degrees of adjustability as well as quality. Three specific products shall be discussed, all of which were found on AbleData.com

Able Table- a product by Weir Enterprises. This product offers an affordable, light weight, and fairly flexible option. However this product does not adjust to the exact position needed for this project. Also the product description states it is fragile if handed roughly.

Able Table

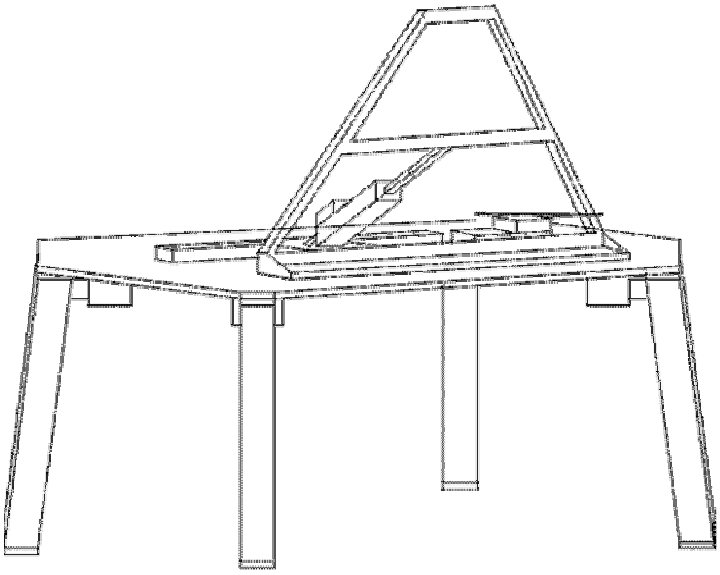
Versa-Table- A product by KayJae. This product is also an affordable, lightweight option that offers easy storage. However it is not nearly adjustable enough.

Versa-Table

The Dreamer- This product is motorized, extremely adjustable, and allows for large canvases. However, it has motors, is very large, expensive and offers no storage options.

The Dreamer

Previous Project Design- The Accessible Easel in Spring 2003. This product offered good adjustability, sturdy frame, and motorized adjustment. However its adjustability was not specific enough, exposed wires caused a problem, and was not portable.



Accessible Easel

1.3.2 Patent Search Results

Besides products that were available on the market it was important to also perform a patent search. Upon searching the term “adjustable easel” with the United States Patent office seven items were found. Most of the seven items did not overlap

with the Easel 5000 because they were devices that were not designed for a disabled person. Many of the designs were for folding or collapsible easels. There was one easel design that was specifically designed for a disabled person but made use of a crank instead of locking joints. Included below are some of the patent numbers and short descriptions of the patents found.

Patent number	Patent Name
6,045,108	Inclined adjustable easel with slidably drawer A multi-purpose easel is provided for use by children, artists, and the like
5,074,513	Adjustable easel An easel adapted for use by disabled persons provides a frame for holding a canvas which can be tilted by means of a crank
D249,533	Foldable portfolio with an adjustable easel The ornamental design for a foldable portfolio with an adjustable easel

1.4 Outline for Final Report

The remainder of this report will discuss the stages of design and other considerations of the project. The stages of design include alternative designs, the optimal design and then prototype building. Other considerations for the project include realistic constraints such as engineering standards, and manufacturability. Safety and impact as well as life-long learning will also be discussed. The budget and parts break down will be included to see if the $750 dollar mark was met. Finally the report will wrap up with a conclusion, references and acknowledgements.

2 PROJECT DESIGN

2.1 Design Alternatives

During the development of our project, three potential designs were created to address the needs of the client. These three designs were all significantly different in the way they accomplished all of the previously mentioned criteria (see Objectives section) defined by our client, Dr. Brooke Hallowell. In addition, a draw for art supplies was added to the design and integrated into the mechanism that attached the easel to the table.

2.1.2 Design 1

Materials

Traditionally, easels have been made of wood. Wood also provides a much warmer tone than metal and is generally more aesthetically pleasing in an art and creative setting. For this reason, team 3 considered a pine frame.

Lighting

A method of lighting the canvas was required and could not be powered by a wall socket because an electrical cord would have created a tripping hazard in the

environment where the easel was to be used. A light emitting diode, or LED, was the best solution to all of the above requirements. LED's were found to be low cost, have an extremely long life, were durable, and emitted little heat. Various other compact components would not only have been time consuming to construct but fairly expensive. After some research it was found that a pre-constructed LED system intended as a head lamp for camping was the best choice. The price was reasonable at $69.95 and it was very compact. Furthermore, it would have saved time during the construction phase of the project.

Canvas Holder

This part of the design supports the canvas from the back. The backing was designed after traditional easels which utilize a single, wide backing beam with a support lip at the bottom of the backing beam. Since this design had two extension arms, the easel mount had a frame that allowed the backing beam and lip to be attached. The easel mount itself was to be tilted forward and back by a mechanism similar to that of a chalk board. The range of canvas sizes to be supported was 8"x8" to 20"x20".

Canvas Clamp

To secure the canvas in place so that it did not fall on the artist when the easel was tilted forward, a locking mechanism was needed. This mechanism took the form of a canvas clamp. The clamp was a block that was secured to the backing beam by a screw that locked into a metal track. When tightened, this screw would have make contact with the metal track, tightening a rectangular nut set in the track. The pressure here will stop the canvas from any movement, thus lock the canvas clamp in place and secure the actual canvas to the easel.

Easel Extension Arms

This is the part of the design that made the easel Adjustable. The system was symmetrical with two arm extensions on either side. On each side, the arm section attached to the base was 30 inches in length and was joined to the base with a hinge and was locked in place by a drafting board support device. The second arm section extension was attached with a bolt to the first arm section, and secured in place by a sliding rail and screw. Once the easel had been positioned into place, the screw was tightened, thus locking the second arm section.

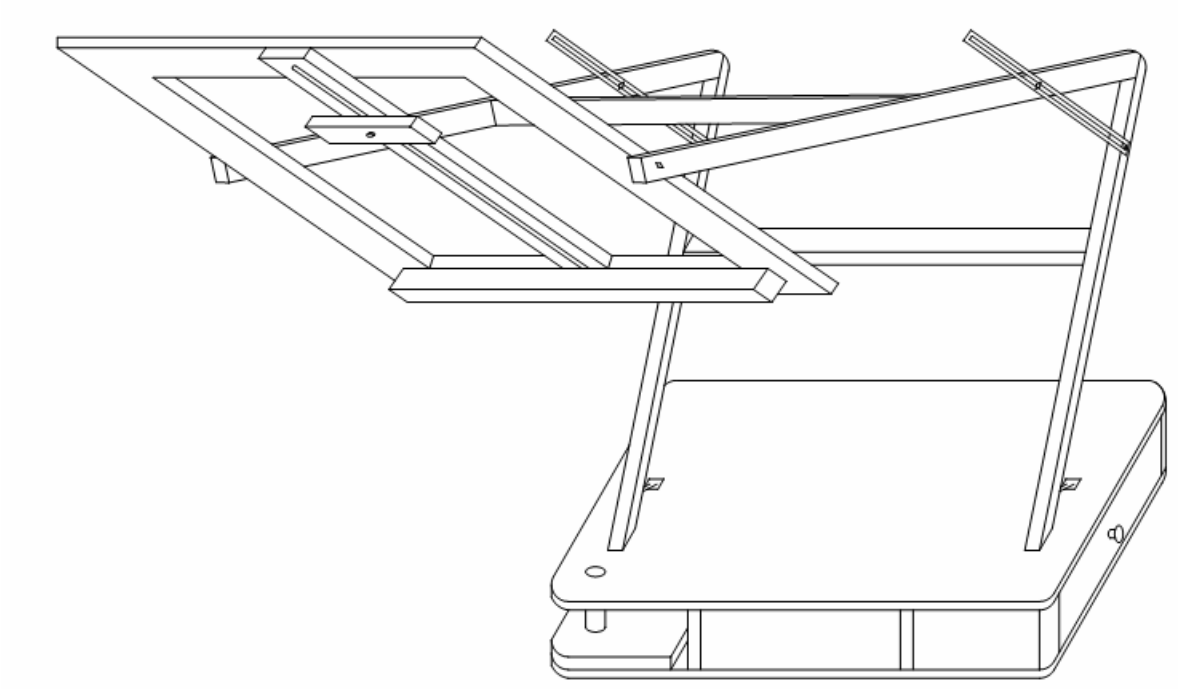


Figure: 3-D conceptual drawing of Design 1

2.1.2 Design 2

Materials

Team 3 decided to use metal for the second design. It had better mechanical properties than wood and the team had received input that wood projects had turned out poorly in the past.

Lighting

The LEDs being used will be super bright LEDs that are capable of emitting 18 candela of light, operating with a current of 20 milliamps. 18 to 20 candelas are recommended for illuminating an object for viewing purposes. Six of these LEDs will be set up in a circuit with resistors, a 9 volt battery power supply, and an on off switch. They will be arranged in a string in order to illuminate across the entire surface of the canvas.

Canvas Holder

The bottom piece will be a square ¾" x ¾" aluminum tube, 23 inches in length, and will act as the canvas sill to support the bottom of the canvas. In order to increase the coefficient of friction on this piece, a rubber strip was to be attached to the sill so that the canvas will not slide off as easily. Perpendicular to this piece were three square ¾" x ¾" aluminum tubes to support the back of the canvas. These pieces were to be 26 inches in length and welded toward the middle of the sill. An extrusion was welded to the top of these three pieces, in order to provide stability and so that the canvas clamp would not be able to slide off.

Canvas Clamp

An aluminum extrusion was used for the canvas clamp. This extrusion was to be a ¾" x ¾" beam and would have had an adhered rubber strip attached to the surface in order to increase the coefficient of friction where the canvas will make contact. The clamp was locked into position using 2" x 1" aluminum channels and wing-nuts. The pressure on the canvas by the clamp was to stop the canvas from any movement, thus locking it in place.

Easel Extension Arms

A roller mechanism was used to extend the canvas holder. A roller cage mounted to the easel base was to have a square ¾" x ¾" aluminum tube run through the center of it. This aluminum tube was to have holes drilled in the sides so that it could be locked into position once extended. The roller cage itself was to be adjustable up and down so that it could increase or decrease the elevation of the entire canvas holder. This elevation adjustment was to be accomplished through the use of a gas spring.

Canvas Base

After researching products that attach to a table top, it was found most of these products made use of a C clamp. Instead of using C clamps it was decided that making the base a C clamp itself would be the best way to attach it to a table top. By constructing the base in a modified C shape it would allow it to slip over the edge of a table and lock down.

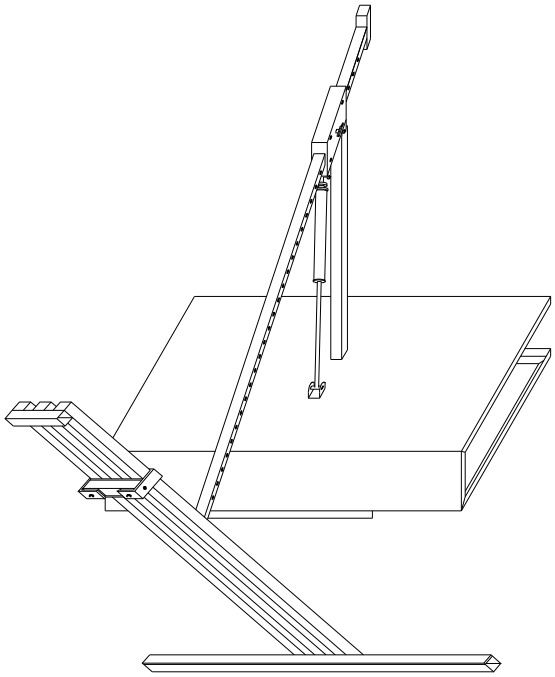


Figure: 3-D view of Design 2

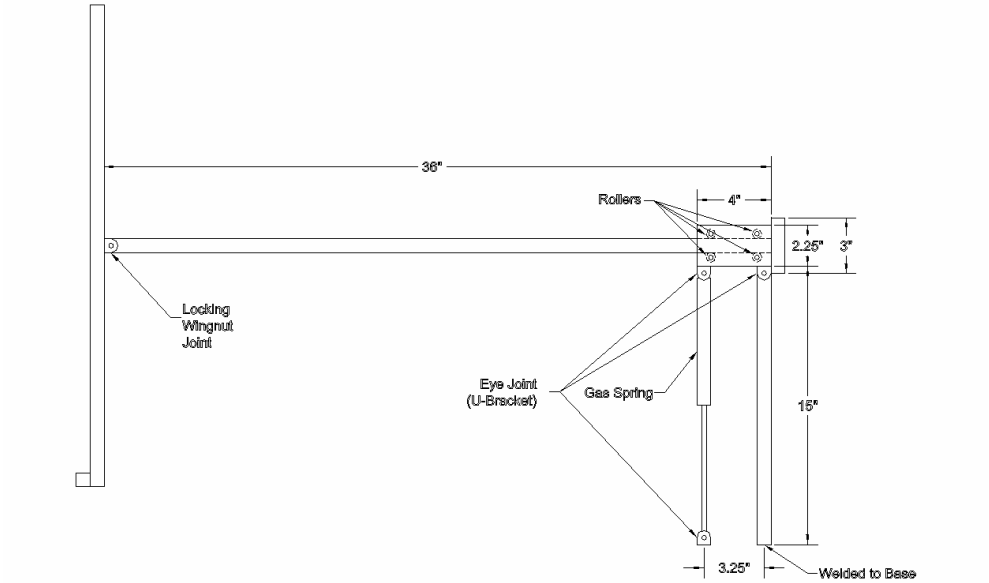


Figure: Side view of Design 2

2.1.3 Design 3

Materials

This design was made of aluminum.

Lighting

LEDs were also used for design 3. A prefabricated LED reading light was chosen as the illumination source for this particular design. The light had three LED bulbs, each of which was designed to last up to 10,000 hours. The articulation for the light allows for a wide range of movement in order to reach every part of the canvas. The light runs off of three button batteries that are easily replaced.

Canvas Holder

The bottom piece will be a square ¾" x ¾" aluminum tube, 23 inches in length, and will act as the canvas sill to support the bottom of the canvas. In order to increase the coefficient of friction on this piece, a rubber strip was to be attached to the sill so that the canvas will not slide off as easily. Perpendicular to this piece were three square ¾" x ¾" aluminum tubes to support the back of the canvas. These pieces were to be 26 inches in length and welded toward the middle of the sill. An extrusion was welded to the top of these three pieces, in order to provide stability and so that the canvas clamp would not be able to slide off. Of those 3 vertical pieces, the center aluminum tube would have a u bracket welded to the back so that it could join the extender arm.

Canvas Clamp

An aluminum extrusion was used for the canvas clamp. This extrusion was to be a ¾" x ¾" beam and would have had an adhered rubber strip attached to the surface in order to increase the coefficient of friction where the canvas will make contact. The clamp was locked into position using 2" x 1" aluminum channels and wing-nuts. The

pressure on the canvas by the clamp was to stop the canvas from any movement, thus locking it in place.

Easel Extension Arms

Locking and moving the extension arm was accomplished with locking gas springs. These were chosen because they were able to provide a system for easily adjusting and locking the easel in position. Two gas springs were to be involved in the overall operation of the system. The first was to support the first section of the arm. This section had two, parallel, square aluminum tubes, and was attached to the easel base by an eye joint. The second section was pinned to the first and was articulated by a second locking gas spring.

Canvas Base

After researching products that attach to a table top, it was found most of these products made use of a C clamp. Instead of using C clamps it was decided that making the base a C clamp itself would be the best way to attach it to a table top. By constructing the base in a modified C shape it would allow it to slip over the edge of a table and lock down.

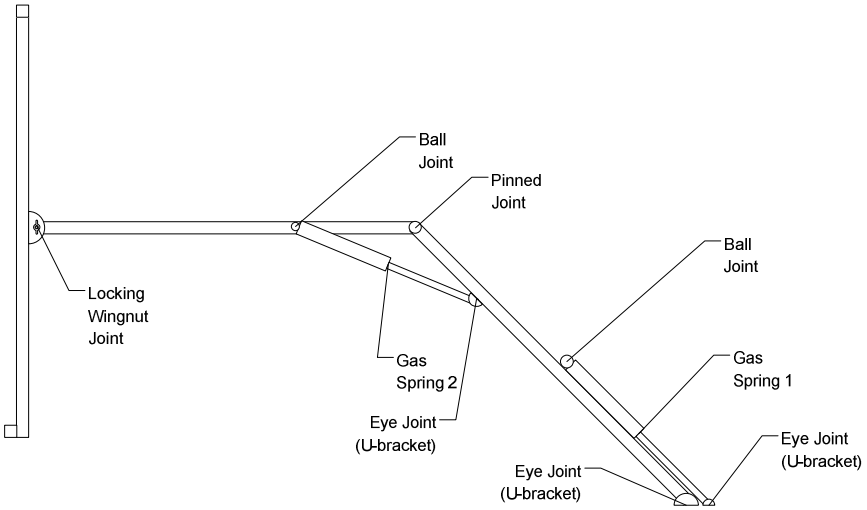


Figure: Side View of the Exension arm, and Canvas holder.

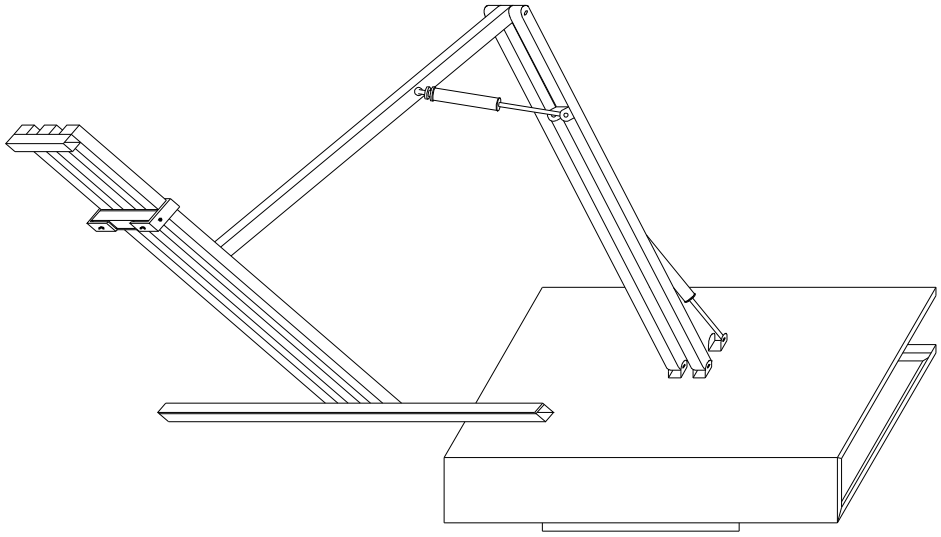


Figure: 3-D view of Design 3. (w/o light)

2.2 Optimal Design

Team 3 chose to use components from design 2 and design 3 for the optimal design. The lighting system from design 2 was selected because it was challenging and also feasible for construction because the cost of the easel was far below the total allotted budget for the project. The canvas holder and clamp, the extension arm, and the base were taken from design 3.

This particular canvas holder was selected for the simplicity of construction, strength of materials and overall support provided to the canvas itself. The rubber attached to the lip of the canvas holder was also considered to be advantageous when locking the canvas in place. The clamping mechanism was also quite simple in operation and would lock the canvas in place sufficiently due to the rubber stripping designed into the canvas clamp and metallic construction.

The gas spring-aided locking articulation from design 3 was selected because it provided an easy way of adjusting the easel extension arm, locking it into place and used a ball joint. It was also selected because releasing the adjustment should allow for gradual repositioning as opposed to the abrupt release of the screw locking mechanism present in the other two designs.

The base is also relatively simple in construction and locking concept. It also provides some weight to the device so when the extension arm is locked in position, it will stay locked into position and fastened to the table securely.

The optimal design incorporates what team 3 believes to be the best assets of the three designs into one design. The design has no electrical cords, is lighted, is easily adjustable, and can be transported from one spot to another with relative ease. Because of the metal construction, the easel should be durable enough for everyday use. Overall, this design fulfills the objectives of the project, simply, effectively, and under budget.

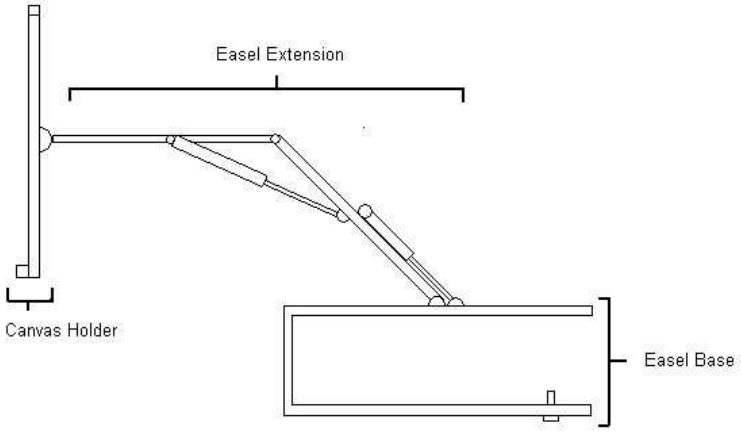


Figure: Side view of the optimal design.

2.2.1 Objective

Project Easel 5000 is a cooperative effort between UConn's Biomedical Engineering Senior design class and the National Science Foundation, or the NSF. The specific project being worked on for the NSF is called "Engineering Projects to Aid Persons with Disabilities." The objective of project Easel 5000 is to build a new adjustable easel for an artist with cerebral palsy. Previously, an adjustable easel was designed in 2003. However, it did not completely fulfill the needs of the artist. The first design did not have the adjustability needed. It also had a motor that the artist had difficulty using and was a tripping hazard because of the motor's electric cord at the location where it was used.

The objectives of the project are to build a new adjustable easel that meets the specifications presented by the NSF. These specifications fall into four main categories: environmental, electrical, mechanical, and economical. The environment the easel will be used in will require it to portable, table top size, and easily used in a busy art room setting. The electrical requirements will include a cordless light source with an easy on/off switch. Mechanically, the easel will need stability, flexible locking joints, and be able to accommodate a 20" x 20" canvas. Economically, the design and construction of the easel must cost less than $750.

The easel design can be broken down into five major components. The components are the light source, the adjustable easel mount, the canvas holder, the easel extension, and the base.

2.2.2 Subunits

LIGHT SOURCE

The light source for the Easel 5000 must be battery operated to reduce any tripping hazard that could result from a power cord. It must be lightweight and compact, yet provide sufficient light to illuminate the canvas surface. An easy on/off switch is also desired for ease of use. Also, it would be beneficial if the light source was energy efficient and required minimal battery changes.

A light emitting diode, or LED, is the best solution to all of the above requirements. LED's are low cost, have an extremely long life, are durable, and emit little heat. A panel mount string LED system will be used at the top of the canvas holder to illuminate the canvas. The LED string will be mounted inside an aluminum architectural angle bar. The bar will then be attached to the top of the canvas holder with a piano hinge to allow for the positioning of the light source.

The LEDs being used will be super bright LEDs that are capable of emitting 18 candela of light, operating with a current of 20 milliamps. 18 to 20 candelas are recommended for illuminating an object for viewing purposes. Six of these LEDs will be set up in a circuit with resistors, a 9 volt battery power supply, and an on off switch. They will be arranged in a string in order to illuminate across the entire surface of the canvas.

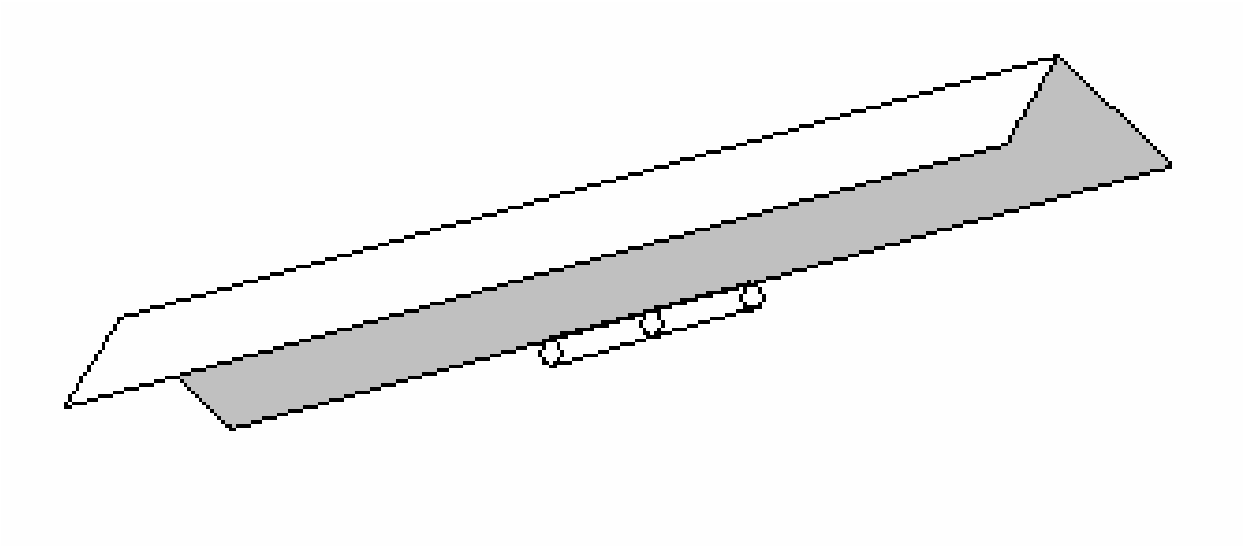


Figure 1: Light mount

Spec	Value
Product ID	L1-0-W5TH15-1
Angle	15
Package	5mm
Color	
Peak Wavelength in nm	
Luminous Intensity	18000mcd typ. @ 20mA
Max Forward Current	30mA
Max Forward Current Pulse	100mA for <= 10ms, duty <= 1/10
Forward Voltage	3.6V typ. 4.0V max @ 20mA
Max Reverse Voltage	5V
Power Dissipation	120mW
Operating Temp	-30 to +85 C
Soldering Temp	265 C for 10 secs
Max Reverse Current	50uA @ 5V

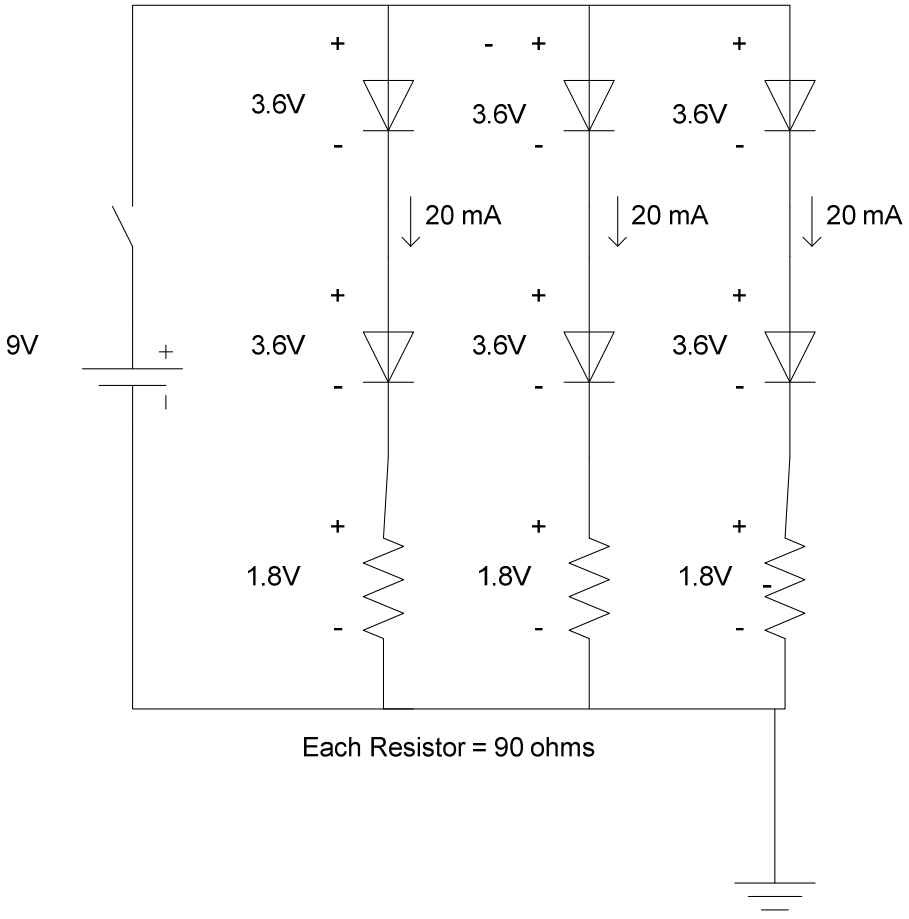


Figure 2: Circuit for LED system

LED SYSTEM ANALYSIS AND CALCULATIONS

-Each LED has a 3.6 voltage drop
-Each LED requires 20 milliamps to operate at 18 candela

For one branch of the circuit
3.6V + 3.6V = 7.2V

Kirchoff's Voltage loop
Voltage across the resistor = 9V – 7.2V = 1.8V
Current across the resistor = .02A

Ohm's Law
R = V/I
R= 1.8V/.02A = 90 ohms

To ensure there is not too much wattage lost in the resistor
Watts = I*V = .02A*1.8V = .036 W

CANVAS HOLDER

The canvas holder will be the portion of the easel that holds the canvas onto the easel. The canvas holder used in this design is very similar to basic easel designs. The easel will hold the canvas and will be the support for the painting. It is to be designed to be capable of holding canvas sizes up to 20" x 20". The canvas holder will be produced out of ¾" x ¾" aluminum extrusions. Aluminum is cost effective as well as lightweight and can mechanically provide the strength and support necessary for the design.

The bottom piece will be a ¾" x ¾" aluminum extrusion, 23 inches in length, and will act as the canvas sill to support the bottom of the canvas. In order to increase the coefficient of friction on this piece, a rubber strip will be adhered to the sill so that the canvas will not slide off as easily. Perpendicular to this piece will be three aluminum extrusions to support the back of the canvas. These pieces will be 26 inches in length and welded onto the sill extrusion. At the top of these three pieces, an extrusion will be welded in order to provide stability and so that the canvas clamp will not be able to slide off. See Figure 3 for a detailed front view of the canvas holder.

A final aluminum extrusion will be used for the canvas clamp. This extrusion will also be a ¾" x ¾" beam and will also have an adhered rubber strip to the surface in order to increase the coefficient of friction where the canvas will make contact. The clamp shall be locked into position using 2" x 1" aluminum channels and wing-nuts as shown in the top view of the clamping device in Figure 4. The pressure on the canvas by the clamp will stop the canvas from any movement, thus locking it in place.

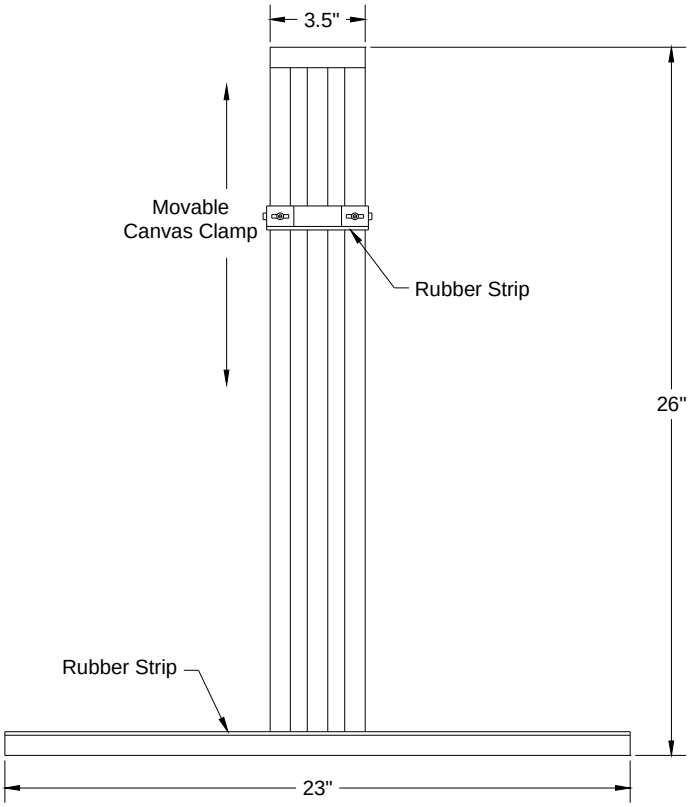


Figure 3: Front view of canvas holder

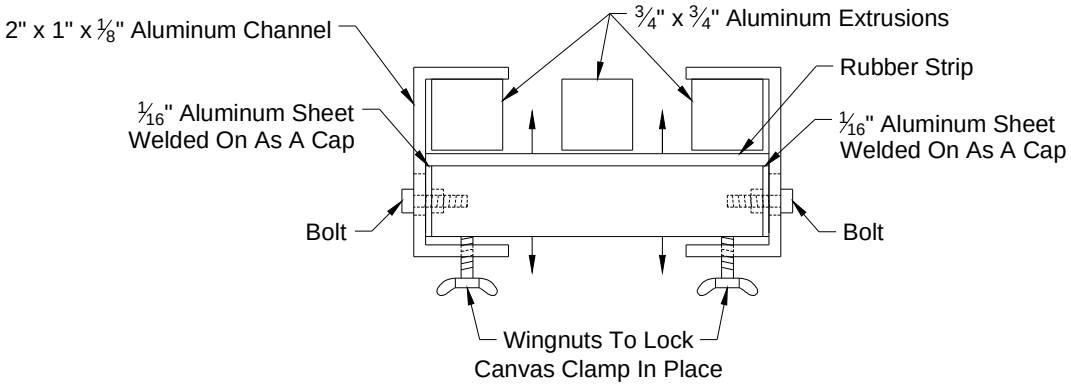


Figure 4: Top view of canvas clamp mechanism

EASEL EXTENSION

As shown in the materials list, aluminum will be used to construct the extender arms. With the use of this material, the overall weight of the easel will be reduced with minimal effect on the mechanical effectiveness of the design. This design will use three ¾" x ¾" aluminum bars that are 24" long. A single bar will be connected to the canvas mount on one end with an adjustable screw joint. This joint will be accomplished with a U-bracket and a wing-nut. The bar will also be pinned at the other end to the other two bars that will make up the arm. Figure 5 is a side view of the design concept and illustrates the use of a pin to join the two sections of the arm together. The two base beams will be attached to the Easel Base by two U-brackets, also shown in Figure 5. Because this joint is pinned, free motion of the extender arms should be possible.

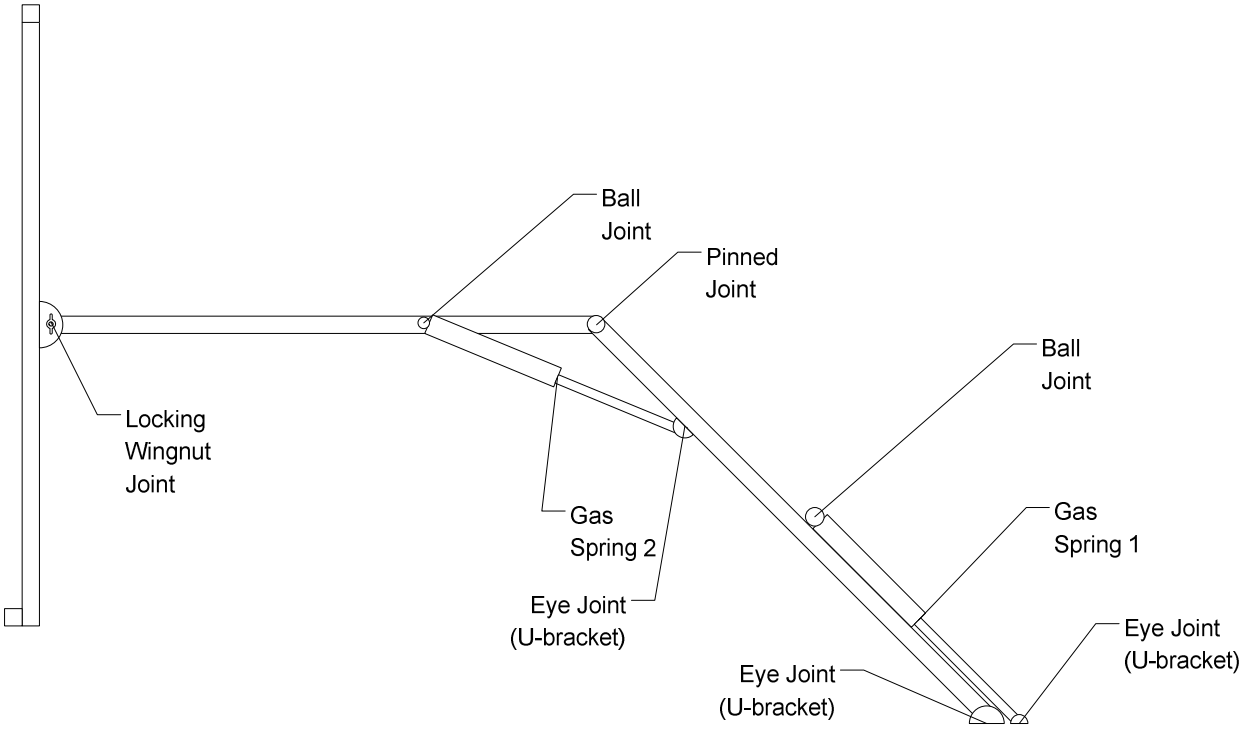


Figure 5: Side view of the easel extender arm and the easel canvas mount

While the joints allow an incredible amount of flexibility, because they are only pinned, another mechanism is required to lock the joint in place. In the search for ways to secure the joints, the muscular system of the body was used for comparison. The arms, legs, fingers and toes are all capable of the type of motion that the easel needs to replicate. These limbs are capable of locking in place and holding up significant amounts of weight. From this inspiration, research was conducted for methods of securing joins by using mechanical linear actuators. However, the easel is not able to use power from a wall socket; using an electrically powered linear actuator is impractical because powering the actuator with battery power would require too large a battery.

Gas springs are similar to electrically powered linear actuators in the fact that they provide linear resistive force. The gas spring operates by a control valve that allows an inert gas, such as nitrogen, to pass freely between two chambers. Closing the

valve stops the flow of gas from one chamber to the other and effectively locks the spring in place. These locking gas springs will hold the extender arm in place. When the arm is to be readjusted, the user will depress the button controlling the spring while simultaneously holding the arm to be adjusted. Because of the light weight of the arm, repositioning the device will be extremely easy.

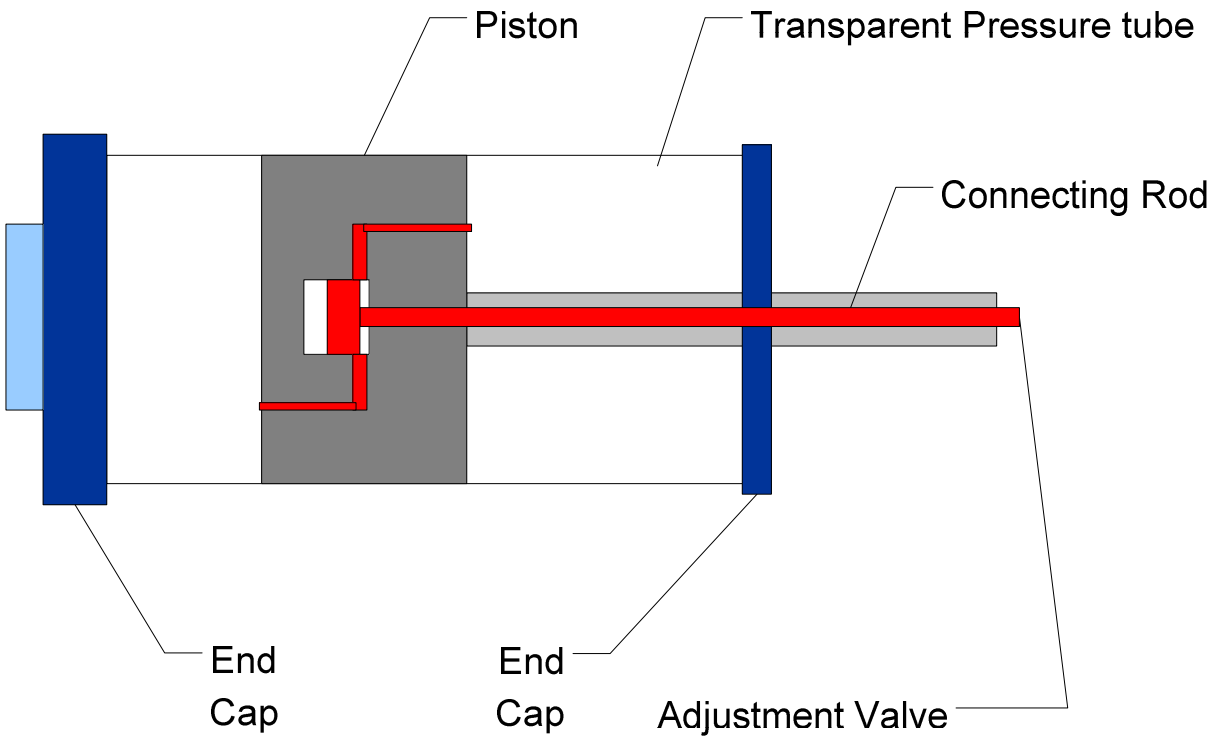
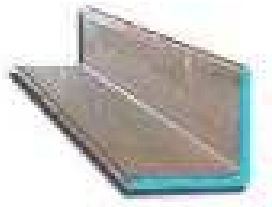


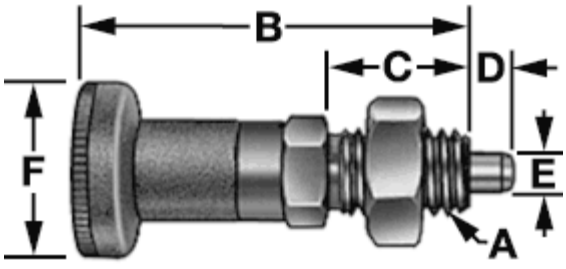
Figure 6: Gas springs to be used to lock the extension arms in place

EASEL BASE

The base of the easel needs to support the rest of the easel and attach to a tabletop. After researching products that attach to a table top it was found most of these products made use of a C clamp. Instead of using C clamps it was decided that making the base a C clamp itself would be the best way to attach it to a table top. By constructing the base in a modified C shape it would allow it to slip over the edge of a table and lock down. Most products on the market that are made for table top attachment accommodate a table that is between 2" and 2 ½" thick.



The base will be made to accommodate tables that are up to 3" thick. Hand-retractable spring plungers will be used along with locknuts mounted to the inside of the frame for locking the base to the table The base will be a framework of ½" x ½" x $^{1}/_{16}$" aluminum architectural angle, covered with 1/16" thick aluminum sheet metal. The base will include a paint brush



ledge and a small slide out shelf for paint brush cleaning. The shelf will be attached to the bottom of the base with sliding rails. See mechanical analysis section for equations and data breakdown.

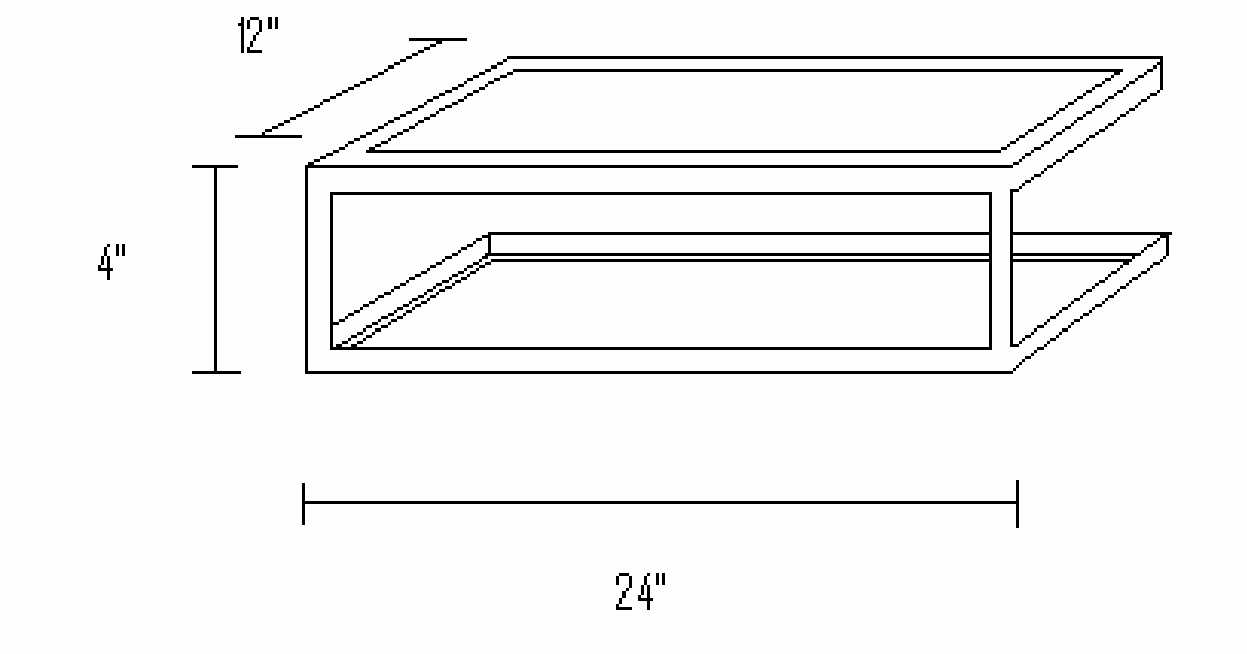


Figure 7: Base frame made of architectural angle

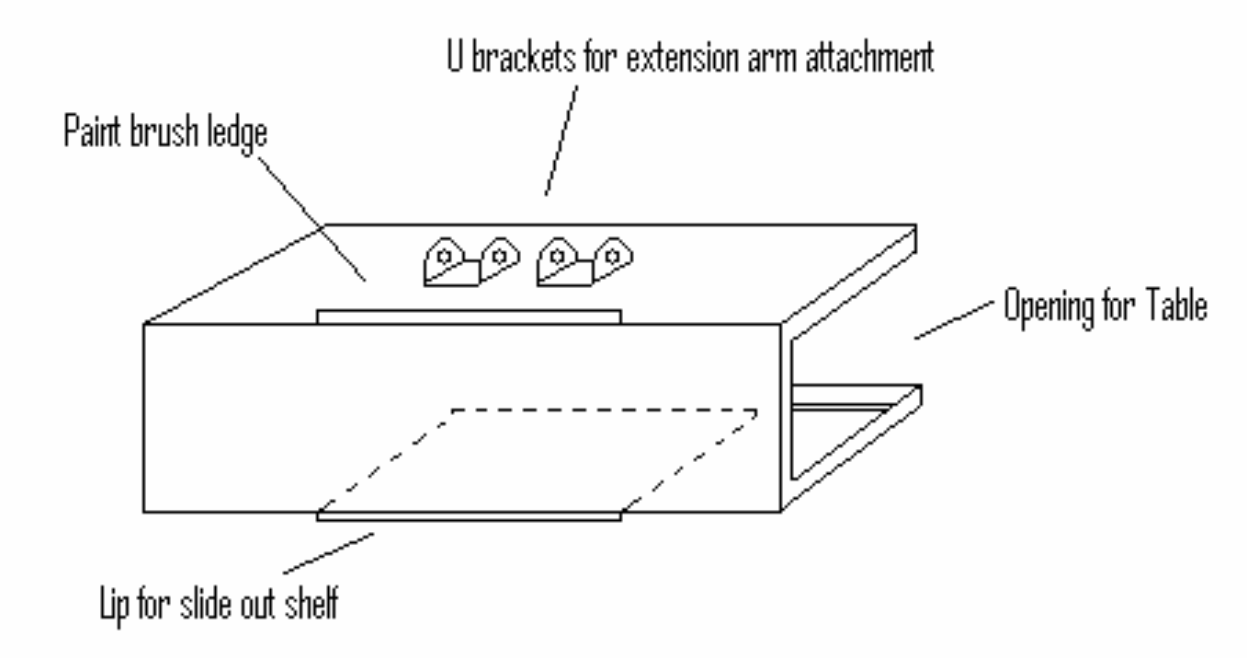


Figure 8: Completed easel base

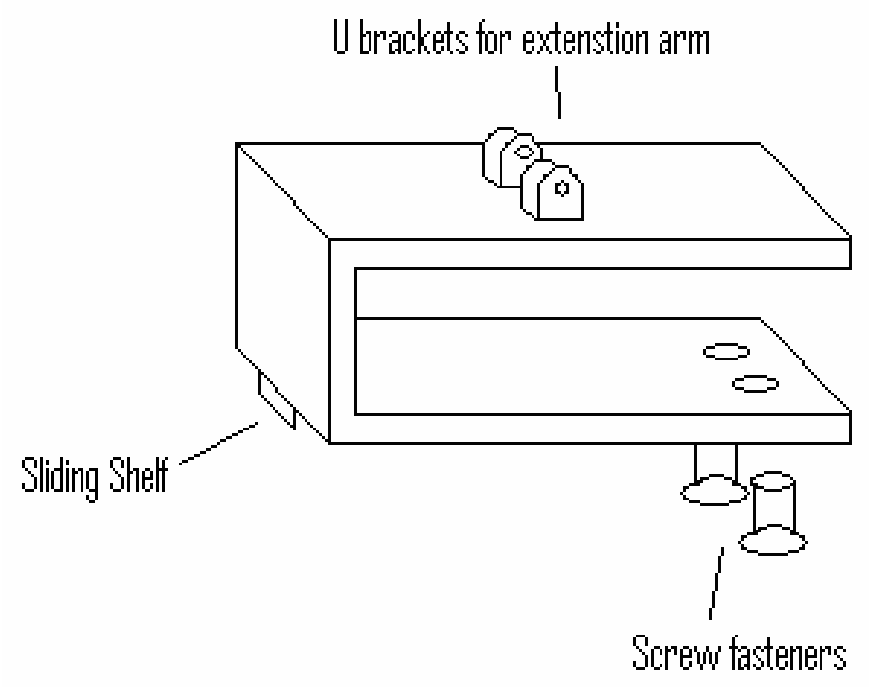


Figure 9: Side view of easel base

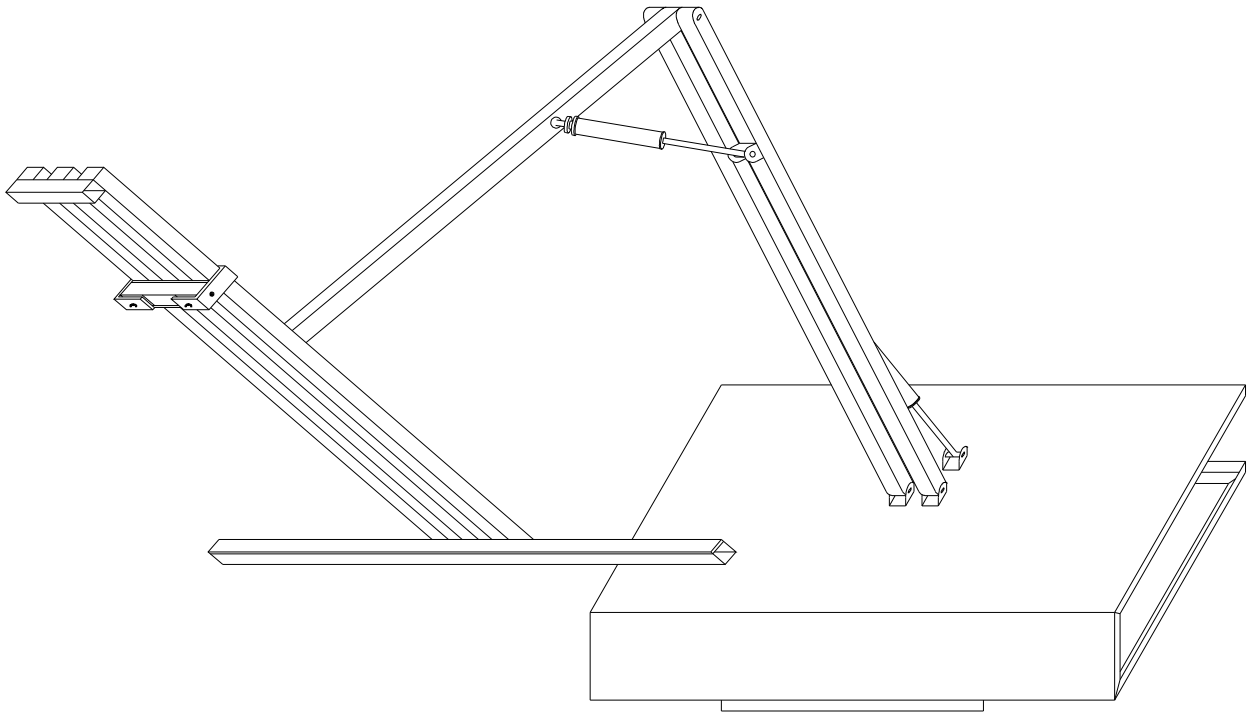


Figure 10: Conceptual drawing of Easel5000

MECHANICAL ANALYSIS

Weight Calculations for Aluminum Pieces

Base	Kind of piece	use	Quantity of piece	piece dimensions (in)		volume (in3)
	architectural angle (.5"X.5"X.0625")	frame	2	4		0.468
	cross sectional area(in2)	frame	4	24		5.616
	0.0585	frame	4	12		2.808
		paint brush ledge	1	12		0.702
						V of angle
						9.594
	use	Quantity of piece	width (in)	length (in)	thickness in	
Sheet metal	top and bottom cover	2	12	24	0.0625	36
	front cover	1	4	24	0.0625	6
	shelf	1	12	12	0.0625	9
	rails	2	2	12	0.0625	3
						V of sheet / weight Al lbs/in3
	arc angle needed in	sheet metal				54 / 0.09
	164					Total volume of the base / Base weight
						63.594 / 5.72346
	Kind of piece		Quantity of piece	piece dimensions (in)		volume (in3)
Easel Extenstion	Square aluminum tube (.75"X.75"X.062")		3	24		12.3696
	cross sectional area(in2)					
	0.1718					
	square tube needed (in)				total volume (in3)	Extension weight
	72				12.3696	1.113264
	Kind of piece		Quantity of piece	piece dimensions (in)		volume (in3)
Canvas Holder	Square aluminum tube (.75"X.75"X.062")		1	23		3.9514
	cross sectional area(in2)		3	26		13.4004
	0.1718		2	3.5		1.2026
	Aluminum Channel (2"X1"X.125")		2	0.75		0.5385
	cross sectional area(in2)					
	0.359					
	Sheet metal	Quantity of piece	width (in)	length (in)	thickness in	volume (in3)
		2	0.75	0.75	0.0625	0.0703125
					total volume canvas	Holder weight
					19.1632125	1.724689125

Aluminum channel needed	square tube needed (in)	sheet metal
1.5	108	

Volume of Entire Easel
95.1268125
Weight of Entire Easel
8.561413125

Base: Mechanical Analysis

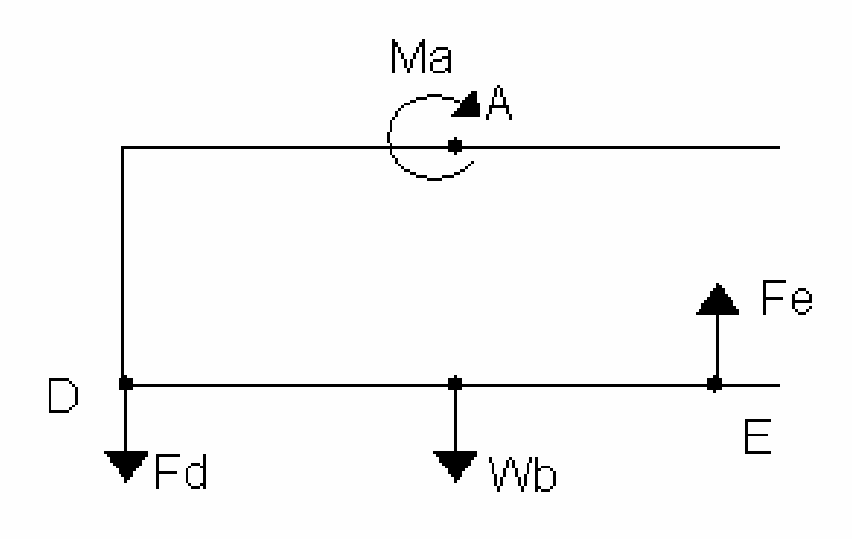


Figure 11: Free body diagram for the base

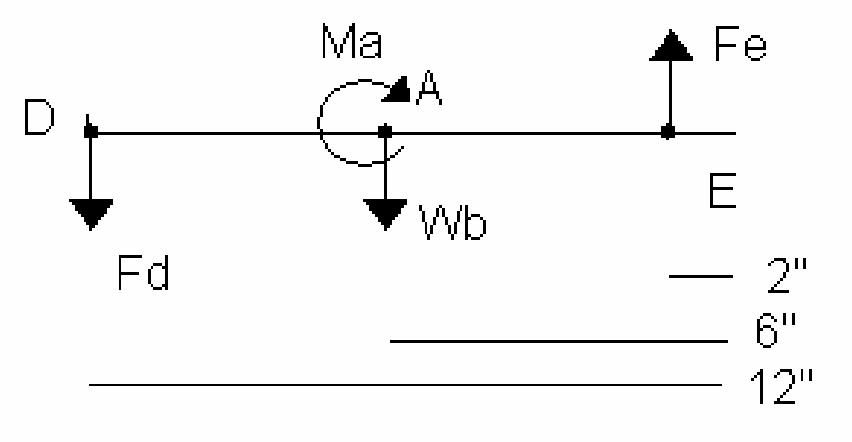


Figure 12: Simplified free body diagram

Definition of Variables

Ma- Moment about A caused by the weight of the extension arms = 117.143 lb*in
Fd- The force exerted on the front of the base
Wb- The weight of the base
Fe- The force exerted on the underside of the table
I_b- Moment of inertia of architectural angle

After doing a moment and force analysis on the base it was found that the force exerted on the bottom of the table (Fe) is a small and reasonable value. It was also observed that the bending stress on the frame would not exceed the bending stress of aluminum.

Bending stress for Aluminum architectural angel at point E
= σ_E = (Ma * Cy)/ I_b

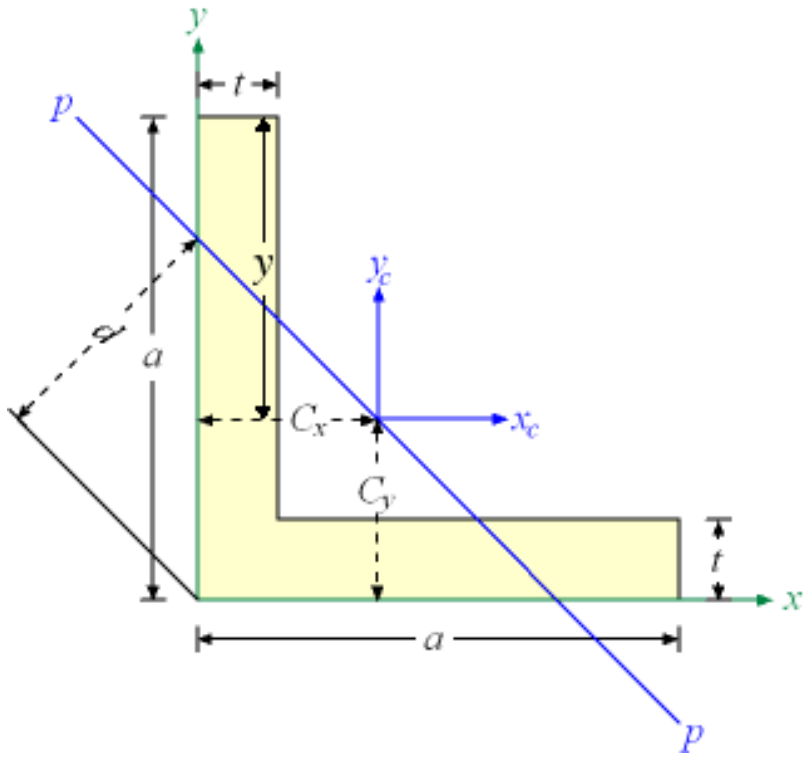


Figure 13: Reference for I_b calculation

I_b Cy

$$\frac{1}{3}\left[ty^3 + a(a-y)^3 - (a-t)(a-y-t)^3\right] \qquad \frac{a^2 + at - t^2}{2(2a-t)}$$

t = 1/16 = 0625
a = .5
Cy = .148
y = a – Cy
y = .352
I_b = .001348 in^4
σ_E = (Ma * Cy)/ I_b = 12,861 psi
Low End Yield strength for Aluminum = 16,000 psi

Bending stress of aluminum at point E (σ_E = Ma*Cy/ I_b) **<** Yield strength for Aluminum

12,861 psi **<** 16,000 psi
Design is effective

Determination of the Force on the Table (F_E)

$\Sigma F_x = 0 : F_E - W_B - F_D$ (1)

$\Sigma M_A = 0 : -M_A + 4F_E + 6F_D$ (2)

Using (2) to solve for F_E :
$M_A - 4F_E = 6F_D$
$4F_E - M_A = -6F_D$
$4F_E = -6F_D + M_A$
$F_E = -1.5F_D + ¼M_A$ (3)

Substituting (3) into (1) :
$0 = -1.5F_D + ¼M_A - W_B - F_D$
$-2.5F_D + ¼M_A - W_B = 0$
$-2.5F_D = W_B - ¼M_A$
$F_D = -0.4W_B + 0.1M_A$ (4)

Substituting values into (4) :
$F_D = -0.4W_B + 0.1M_A$
$F_D = -0.4(5.723) +0.1(117.143)$
$F_D = 9.4251$ lbs.

Using F_D in (3) to solve for F_E :
$F_E = -1.5F_D + ¼M_A$
$F_E = -1.5(9.4251) + ¼(117.143)$

F_E = 15.148 lbs.

Easel Extension Analysis

The easel extension arms need to be examined to ensure that the materials used would stand up to the weight and forces applied to it with reasonable use. To do this, the moments were calculated at each joint pin so that the bending stress could be examined. The moments at each point will also be useful for the calculation of the necessary gas spring strengths needed to support the structure when it is fully extended toward the artist. This particular design should be able to reach a maximum extension of 36” - 40” toward the artist and away from the table. Shown below is a free body diagram used for the moment calculations.

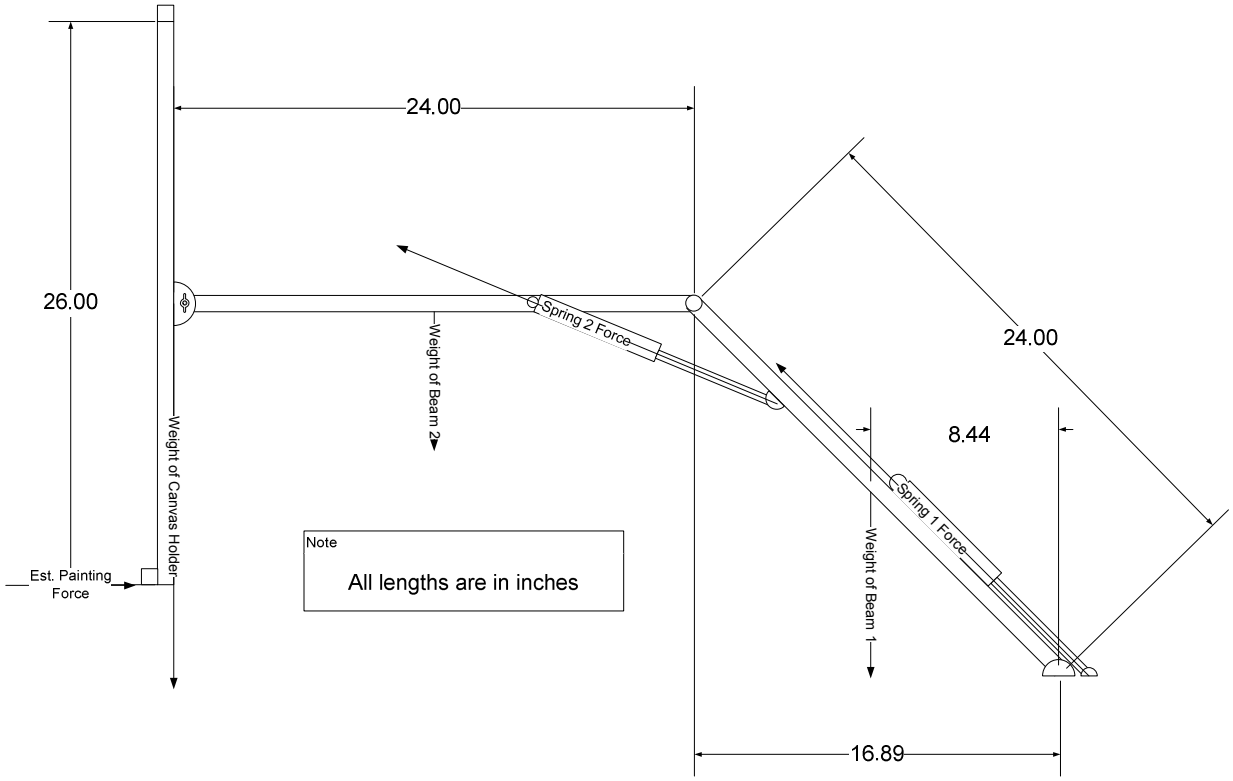


Figure 14: Free body diagram used for the moment calculations

The following table displays calculated moments at points C, B, and A:

Moment about C	variable	value	units
Sum moments about C=0	Mc-Mf=0		
Moment about C = Moment created by F	Mc=Mf		
Moment created by F	Mf=F*Dfc	65	lbs* in.

Moment about B	variable	value	units
Sum moments about B = 0	Mb = Mc + Mb2 + Mcm		
Moment about C	Mc	65	lbs* in.
Moment created by weight of Beam 2	Mb2 = Wb2*Db2b	4.453056	lbs* in.
Moment created by weight of Canvas Mount	Mcm= Wcm*DcmB	41.39254	lbs* in.
Moment B	Mb	110.8456	lbs* in.

Moment about A	variable	value	units
Sum moments about A=0	Ma = Mb+ Mb1t		
Moment created by weight of the two beams Wb1*2	Mb1t=Wb1t*Db1A	6.297572	lbs* in.
moment about B	Mb	110.8456	lbs* in.
Moment about A	Ma	117.1432	lbs* in.

To lock the canvas holder in place so it does not tilt freely, a screw locking mechanism is employed as mentioned before. This type of mechanism should adequately counter the moment created by the estimated painting force. To account for the moment about points B and A, gas springs will be used to stabilize the arm and lock it in place. The following is a table with the minimum amount of force needed to be supplied by each spring. The spring configuration is shown in Figure 5.

Spring 1 Force	variable	value	units	notes
Moment created by spring 1	Ms1=Ma	117.1432	lbs* in.	
Moment about A	Ma	117.1432	lbs* in.	
Spring 1 Force	Fs1=Ma/Dfs1	144.6212	lbs	

Spring 2 Force	variable	value	units	notes
Distance of spring 2 attachment from point B	L1=Ls2*sin(ThetaS2)/sin(ThetaA) L1	6.494353	in.	
Moment about B	Mb	110.8456	lbs* in.	
Moment supplied by Spring 2	Ms2=Mb			
Spring 2 Force	Ms2=Fs2*Dbfs2			
Spring 2 Force	Fs2=Ms2/Dbfs2	44.60082	lbs	

Two locking gas springs were found (shown in the materials list) that are capable of supporting the appropriate amount of force. The use of these springs makes this particular design viable.

Budget

Aluminum 6063-T52

Canvas Holder

Square aluminum tube (.75" x .75" x .062")
(3) 26”
(2) 3.5”
(1) 23” total 108”
Aluminum Channel (2" x 1" x .125")
(2) .75” total 1.5”
Sheet metal .0625” thick
(2) .75” x .75”

Easel Extension

Square aluminum tube (.75" x .75" x .062")
(3) 24” total 72”

Base

Architectural Angle (.5” x .5” x .0625”)
(2) 4”
(4) 24”
(4) 12”
(1) 12” total 164”
Sheet Metal .0625” thick
(2) 12” x 24”
(1) 4” x 24”
(1) 12” x 12”
(2) 2” x 12”

Dimensional Aluminum Needed

Architectural Angle
(2) 8 ft (.5” x .5” x .0625”) ($12.16)
Sheet Metal
(2) 24” x 48” x 1/16” ($61.92)
(1) 12” x 12” x 1/16” ($8.87)
Square aluminum tube (.75" x .75" x .062")
(3) 8’ ($36.48)

Total Aluminum Cost
$119.43

Light

Pack of 10 super bright LEDs ($15.50)
L1-0-W5TH15-1
Resistors, wiring, switch, plastic mount, hinge
Estimate ($10.00)

Others

(2) Extension Lock Gas Spring ($114.72)
Rubber strips for canvas holder ($2.22)
(2) Retractable Spring Plungers ($31.80)
Miscellaneous hardware ($10.00)

Welding Time

10 hour estimate ($100.00)

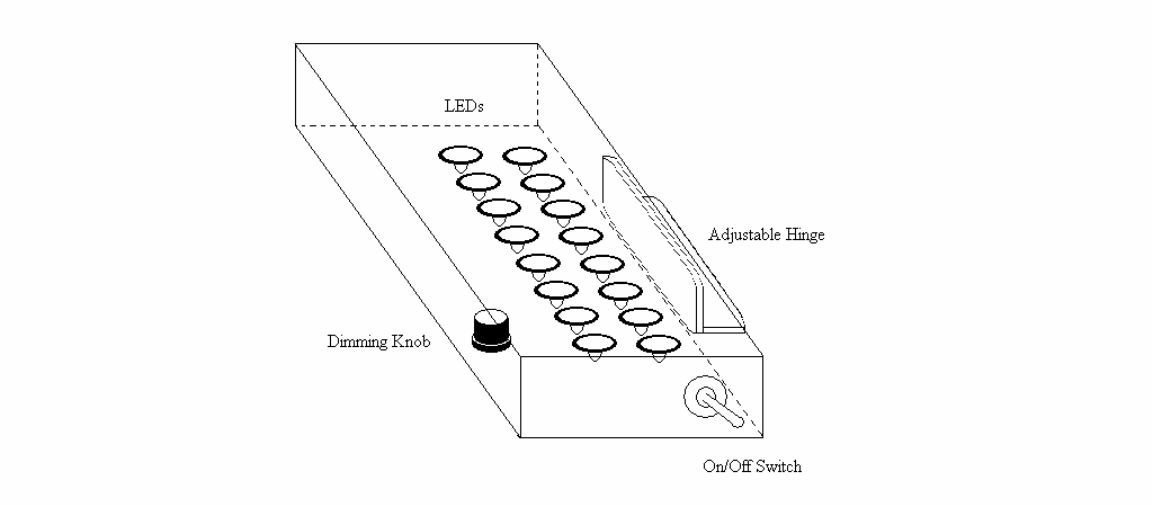
Total Cost Estimate

$403.60

This estimated total cost of $403.60 is well below the budget of $750 set by the National science foundation.

2.3 Prototype

SUBUNITS
LED Light



LED Light

Power Source

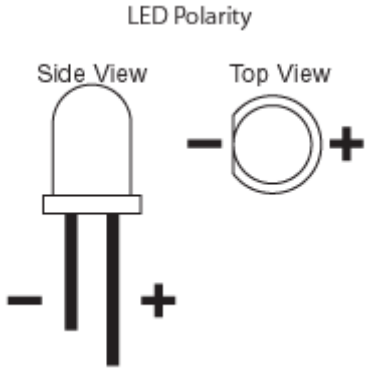
The battery is a 9.6 volt battery pack. It operates at 1700mAh and is a nickel cadmium power supply. It is configured as a flat stick pack with the dimensions 180 X 22 X 45 mm. It also has a standard tamiya connector and includes a 12 volt battery pack charger for use in any standard wall socket. The battery fully charges in 8.5 hours. Its run time is approximately 6 hours. Its input is AC 120 V at 60Hz and its output is DC 12V -200mA.

LEDs

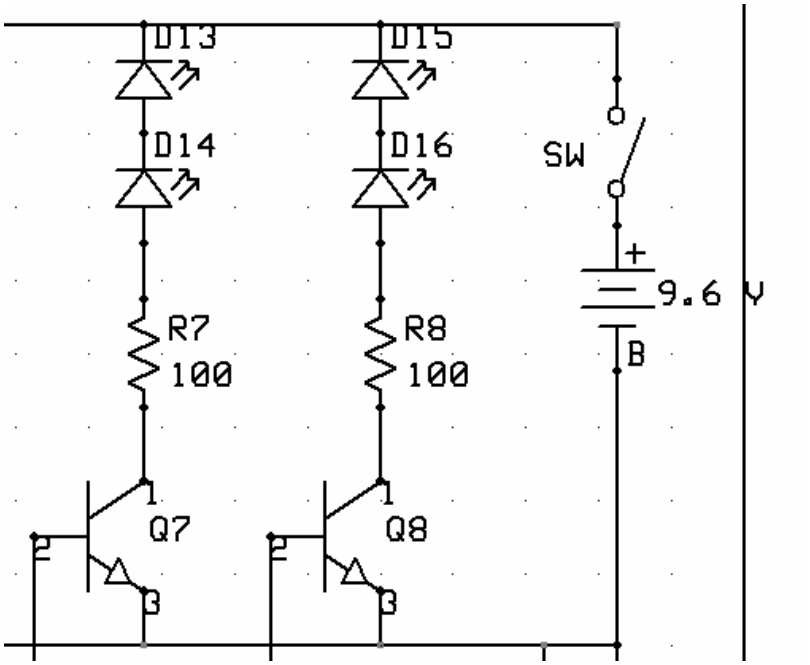
The LED's are super bright 5mm White 18,000mcd. They are some of the brightest white LEDs available on the market today. They are energy efficient as far as how much power they dissipate. They often dissipate less than 100 mill watts of power. Their useable life is longer than 100,000 hours which ensures years of use with

reasonable use. The way the LED works is fairly simple. It is a PN junction semiconductor embedded in an epoxy matrix. This leaves no loose or moving parts to break. When current is applied the diode emits light of a certain intensity based on the magnitude of the current. Most LEDs operate on a current of 20 mA this circuit operates on 25 mA. This current magnitude creates a brightness of 18,000 mcd. This is the recommended brightness for art display in a gallery. Eye safety for an LED this bright becomes an important factor. In order to avoid this problem LEDs with a luminous angle of 15 degrees were chosen. Also the way the friction hinge was installed does not allow the LED enclosure to adjust in the direction of the user. Also the dimming switch allows for a variable brightness. A further feature of the LED light is the low heat dissipation. This ensures the LEDs will not get too hot to cause a safety concern.

LED Spec	**Value**
Product ID	L1-0-W5TH15-1
Angle	15
Package	5mm
Color	
Peak Wavelength in nm	
Luminous Intensity	18000mcd typ. @ 20mA
Max Forward Current	30mA
Max Forward Current Pulse	100mA for <= 10ms, duty <= 1/10
Forward Voltage	3.6V typ. 4.0V max @ 20mA
Max Reverse Voltage	5V
Power Dissipation	120mW
Operating Temp	-30 to +85 C
Soldering Temp	265 C for 10 secs
Max Reverse Current	50uA @ 5V



LED Schematic

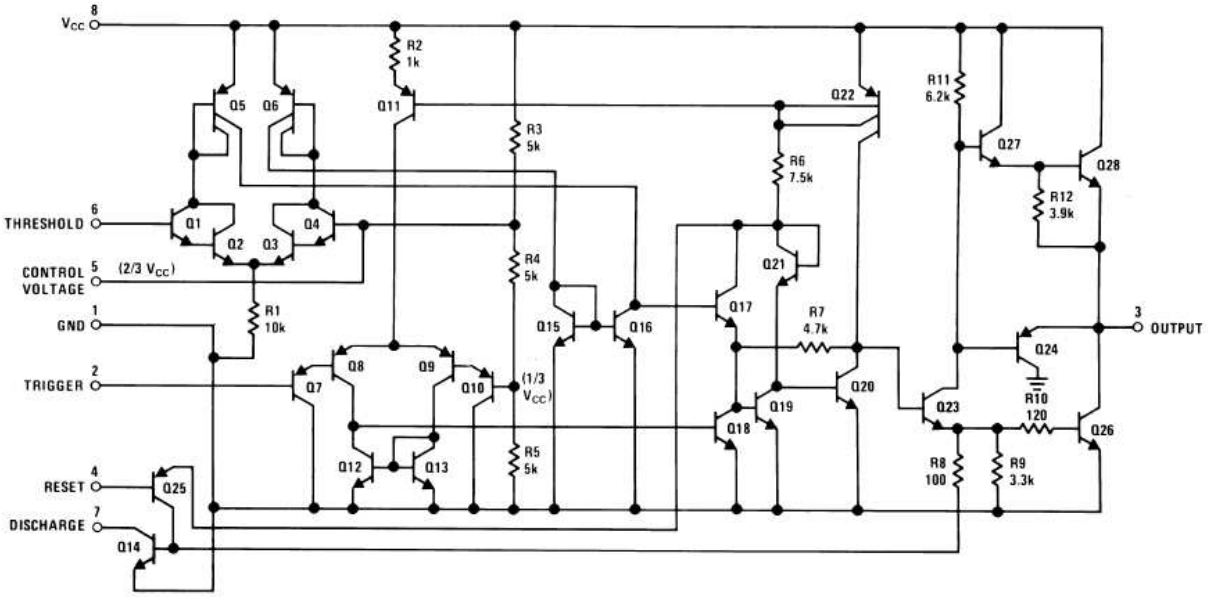


Zoom of Branch of LED Circuit

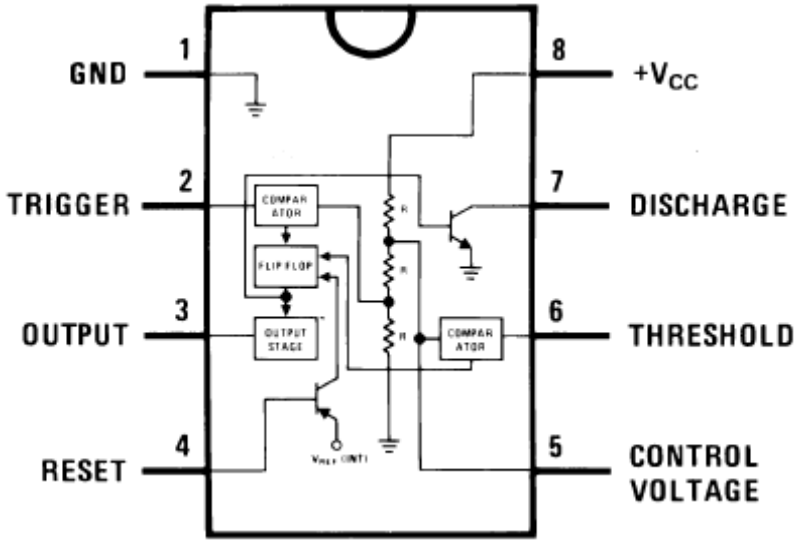
The above circuit shows two branches of the eight branches of the LED circuit. This shows the combination of LEDs in parallel and series. This combination of two in series and eight branches in parallel for a total of 16 LEDs let the circuit operate to maximum capacity. This let the most LEDs run on the smallest power supply the appropriate amount of current to each of the LEDs allowing them to burn at maximum capacity. The NPN switching transistor at the end of each branch is to ensure that the appropriate amount of current is always being provided and the maximum capacity of the LEDs is not surpassed. This is due to the oscillating square wave provided by the LM555 that this problem can arise.

Circuit

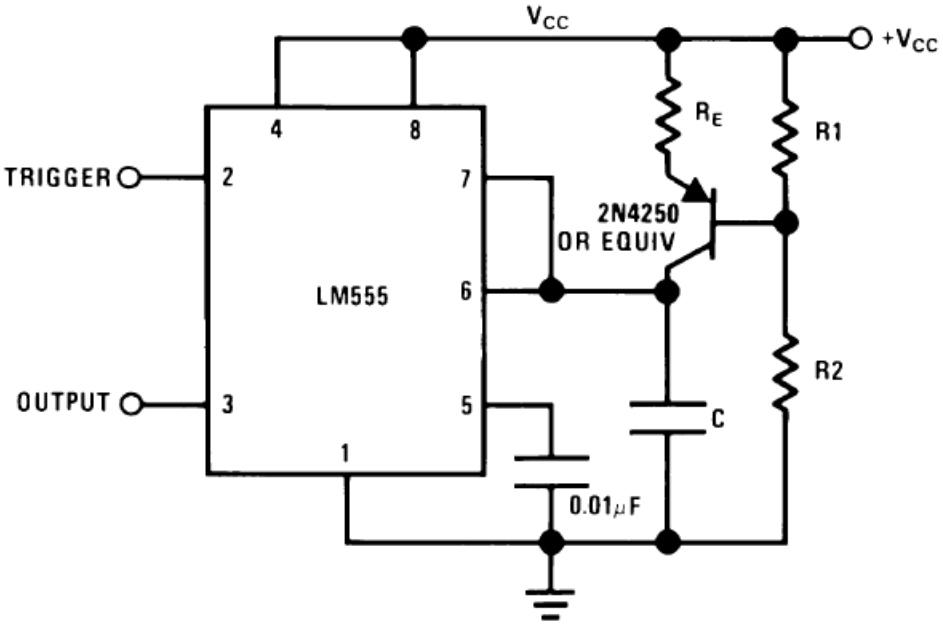
The following is the circuit diagram for the LED light of the product. It includes resistances, LEDs, a power source, transistors, capacitors, an LM555 chip, and a potentiometer. There are important features and characteristics of the diagram to note. The LM555 chip is a highly stable device for generating accurate time delays or oscillation. When configured in time delay mode it is controlled by one external resistor and capacitor. It offers the ability to adjust the oscillating duty cycle through the adjustment of resistor and capacitor values. Coupled with the resistors and capacitors values chosen for this application it creates a square wave power source.



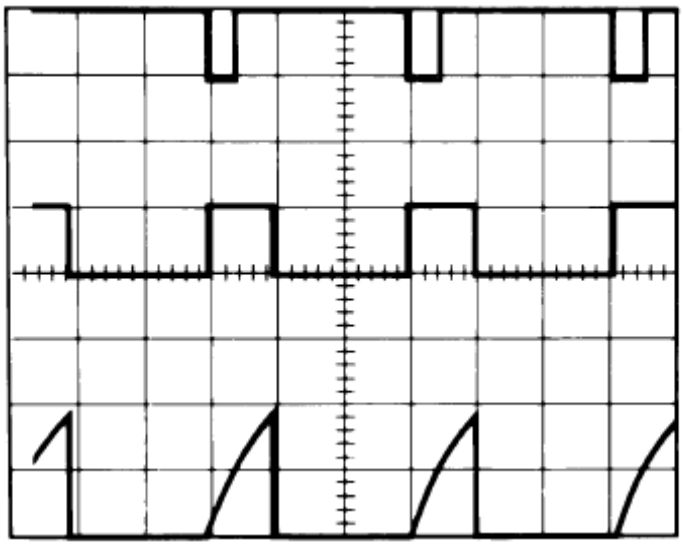
Schematic for LM555 (www.national.com)



Connection Diagram for the LM555 (www.national.com)

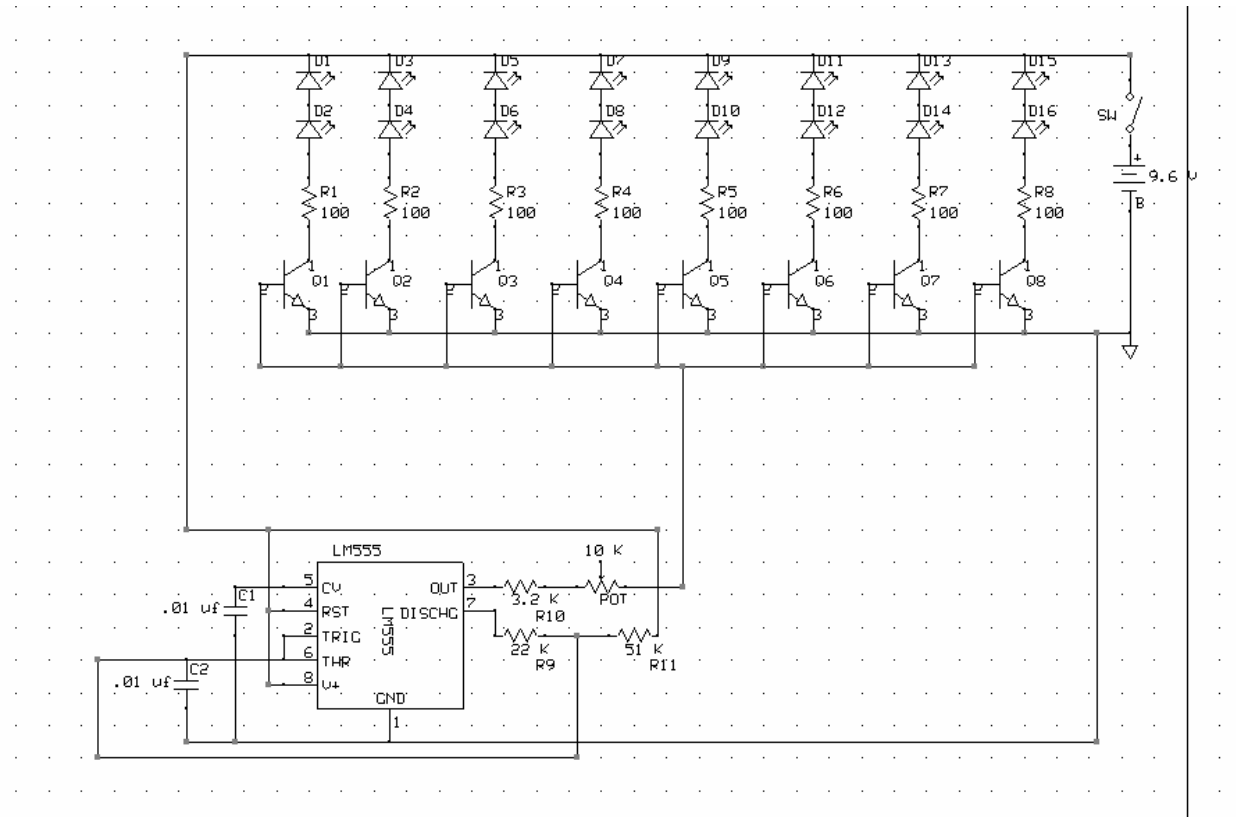


Example of basic setup of LM555 (www.national.com)

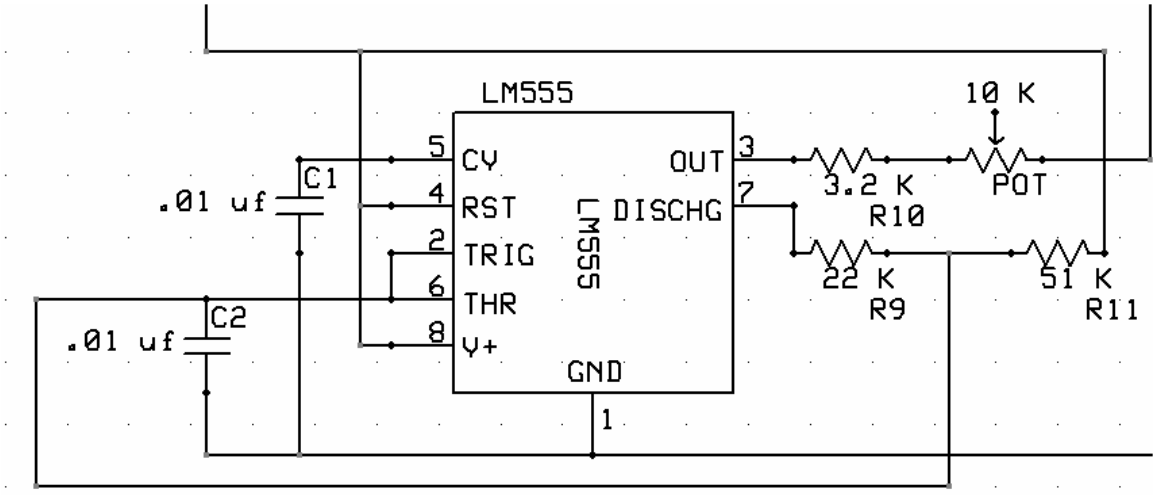


Example of Square waves created with LM555 (www.national.com)

The LM555 makes the LEDs operate off of an alternating square wave. This mimics an AC source and saves battery life by having the LED's flash on and off at a very high frequency so it is not noticeable to the human eye. This means the LEDs are only on half of the time therefore saving LED and battery life. The operating voltage of the circuit is 9.6 volts. There is a 3.6 volt drop across each LED. Each transistor draws 1 mA of current during the on part of the square wave. The potentiometer operates as the dimming switch by creating a larger voltage drop when the resistance is turned all of the way up.



Entire LED Circuit (Express PCB)

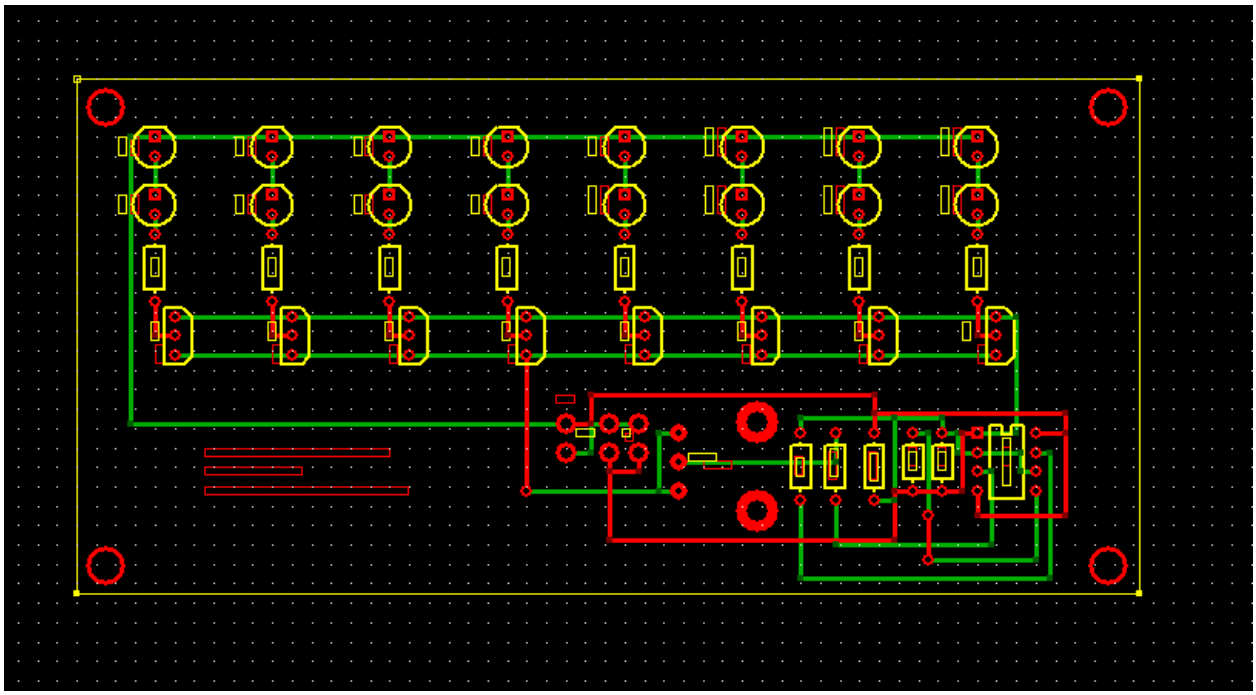


Zoom of LM555 Chip in the Circuit (Express PCB)

The potentiometer operates as the dimming switch by creating a larger voltage drop. When the resistance is turned up to its maximum of 10 Kohm it creates a large voltage drop and gives less voltage and current to the LEDs thus causing them to burn less brightly. However when the resistance is turned all of the way down then the only voltage drop is across the 3.2 Kohm resistor. This causes the maximum amount of voltage and current to be delivered to the LEDs and thus allowing them to burn brightly.

Printed Circuit Board (PCB)

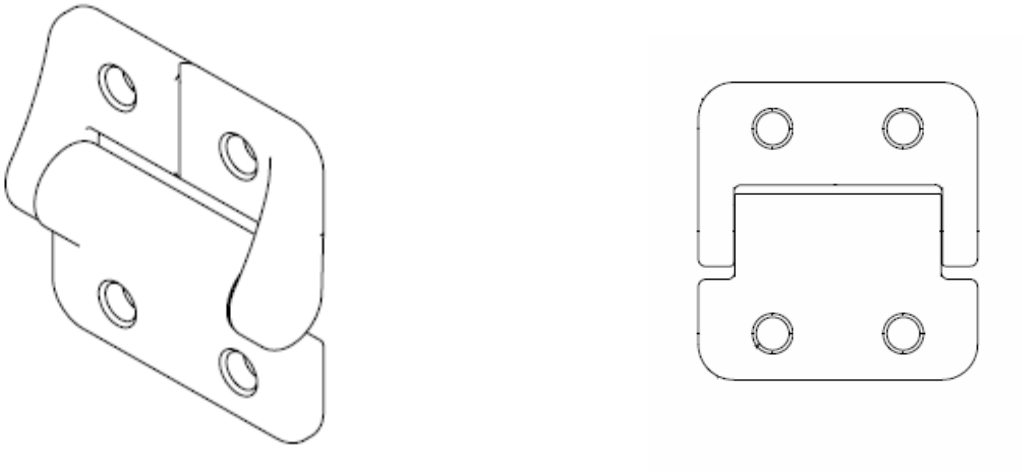
The following is a lay out for the circuit that was adapted to a PCB. This is the way the circuit is set up inside of the LED enclosure. Careful consideration had to be taken when setting up the PCB in order to connect appropriate wires, avoid crossing wires, and avoid shorting components by placing them too closely. This took trial and error and repeated checking of measurements. Further more many custom foot prints had to be made to fit special parts like the switch, battery, and potentiometer.



PCB Schematic (Express PCB)

Friction Hinge

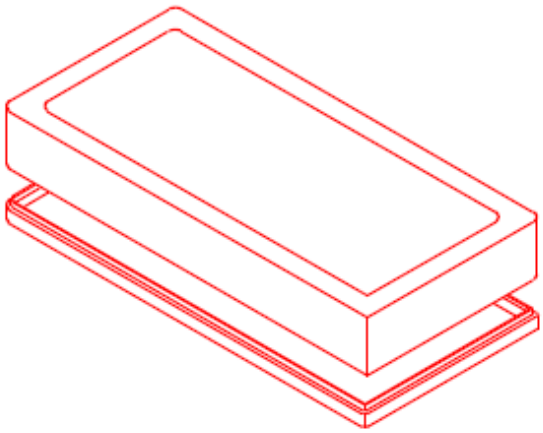
This friction positioning hinge produced by Reell Incorporated operates via a frictional device placed in the articulation between the two hinge pieces. The Model PHC hinge is designed to provide constant torque throughout its full range of motion. The hinge is capable of handling 3.9 lb-in of torque which is more than ample for the small LED enclosure. Also it is capable of more than 10,000 cycles of use at maximum load.



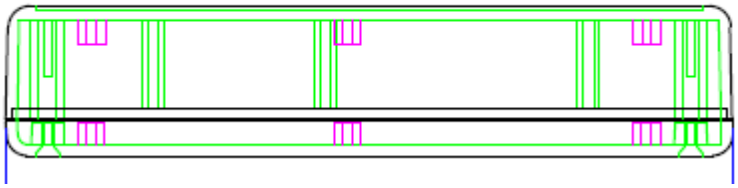
Friction Hinge Side and Front View (Reell.com)

Plastic Enclosure

This prefabricated plastic enclosure by Hammond Manufacturing offered a perfect option for housing the LED lighting unit. The enclosure is made of flame retardant UL94 plastic and has brass inserts in the corners for securing the box closed. It was a good size, offered easy mounting, and was easy to machine for the features of the LED circuit board.



Top View of LED Enclosure (Hammondmfg.com)



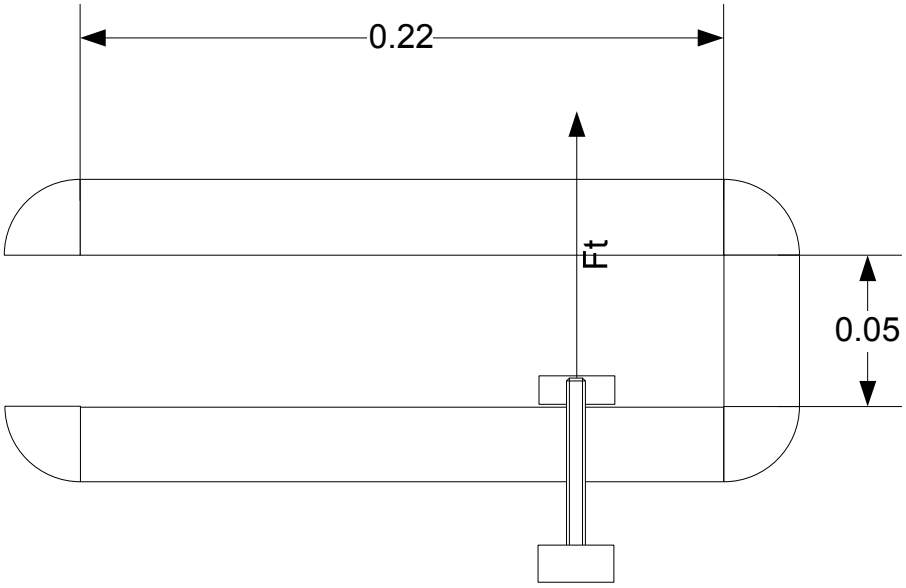
Side View of LED Enclosure (Hammondmfg.com)

Easel Frame

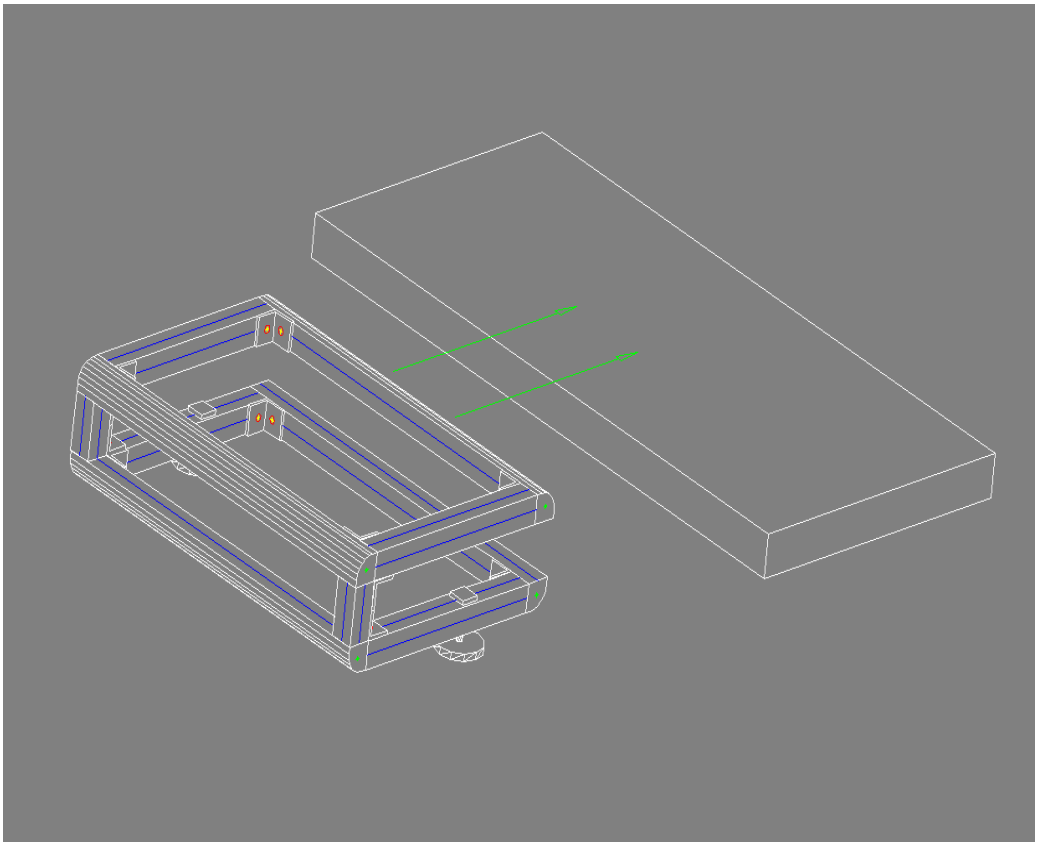
The Easel 5000 consists of four main parts constructed from 80/20 extrusion, and the LED system, which was constructed separately. Each of the four mechanical sections is composed of either 25-2525, 25-2550, or 25-2527 extrusion.

Easel Base

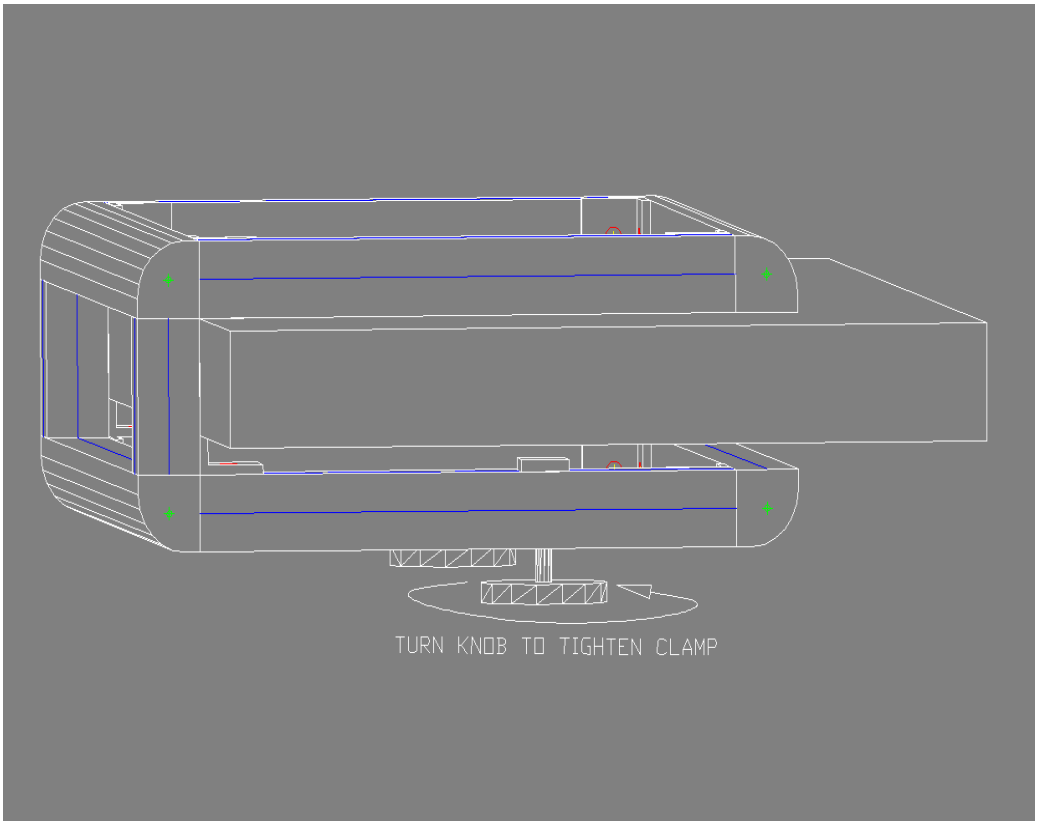
The base was designed specifically to fit the smaller table that attaches to a wheel chair. The particular mechanism for securing the easel to the table is embedded in the base in the form of a C-clamp style locking clamp. The two knobs turn and drive the flat metal plates upward. The metal plates are covered with rubber to avoid scoring the table and to increase friction between the plates and the table. These locking knobs tighten sufficiently to secure the easel so that it may be used. 1.5” (38.1 mm) was taken as the table depth, and the metal plates used are approximately 3/8th inch in depth, leaving a clearance of 1/8th inch to fit the base on to the table.



Easel Base Dimensions



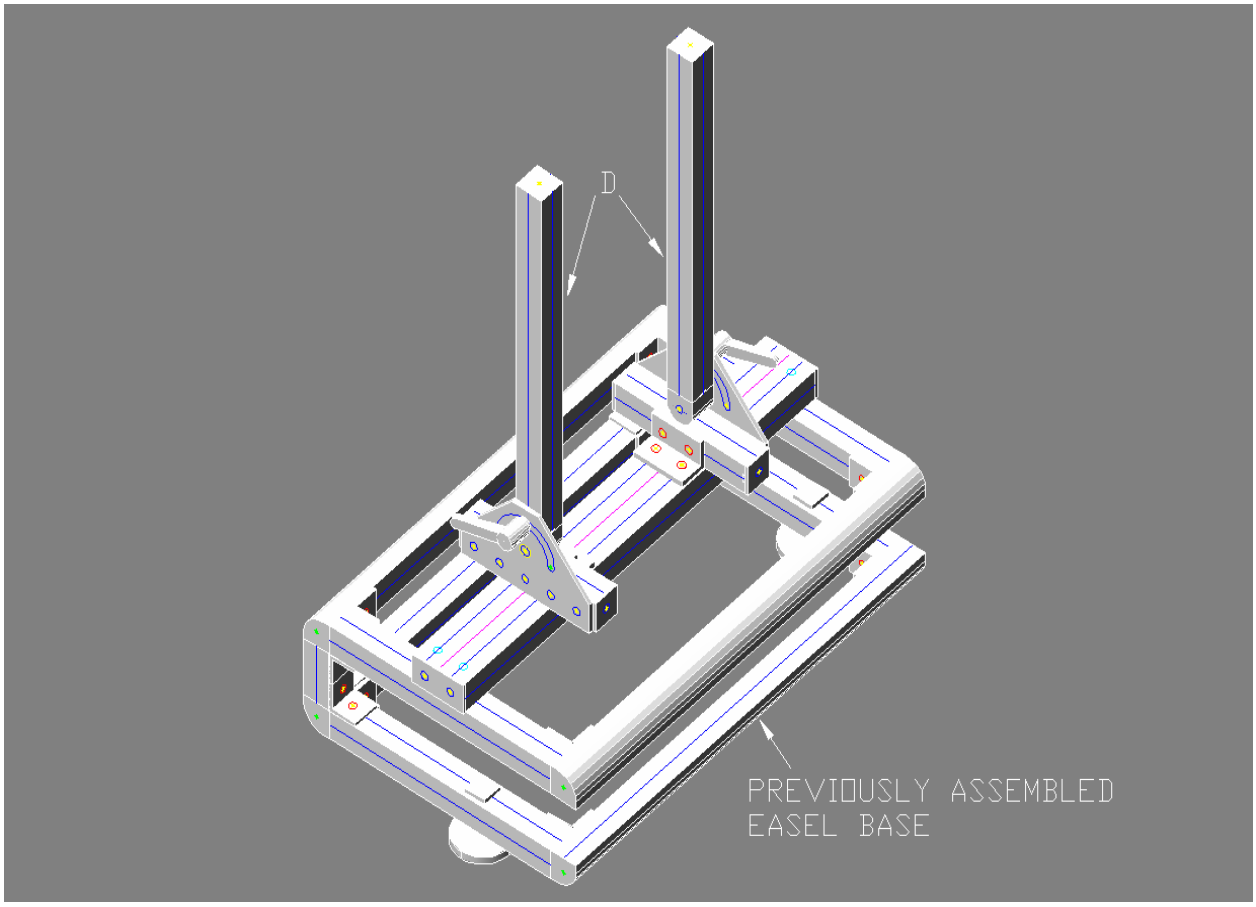
Attaching Easel Base to Wheelchair Tray



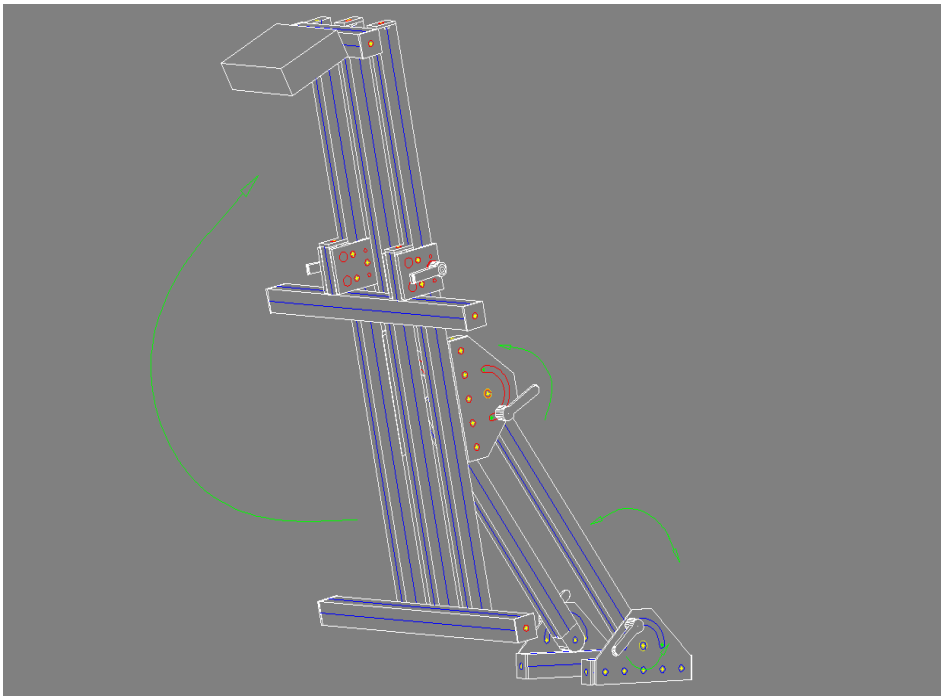
Fastening Base to Wheelchair Tray

Easel Extension Arms

The extension arms were originally designed as a single arm with three joint articulations instead of two. Because of design requirement changes from the first semester, stability reasons and cost constraints, the design was changed to a 2 arm design with two articulations. The range of motion that the Easel 5000 has is large enough so that the easel can be used and has been tested.



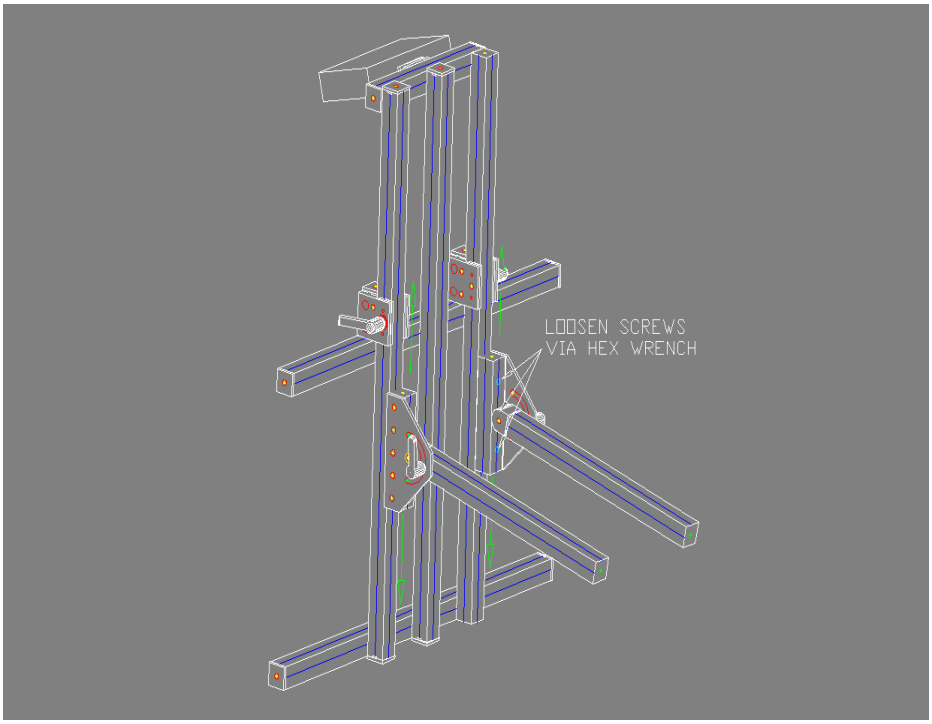
In the diagram above the parts labeled D are the easel arms. Each of the extension arm beams are made of 25-2525 80/20 extrusion that are each 12" (304.8mm) long. At the base are 2 dynamic locking pivot joints which are bolted onto two, 5"(127mm) lengths of 25-2525.



Adjusting the Canvas Position Using Pivots On Extension Arms

Canvas Holder

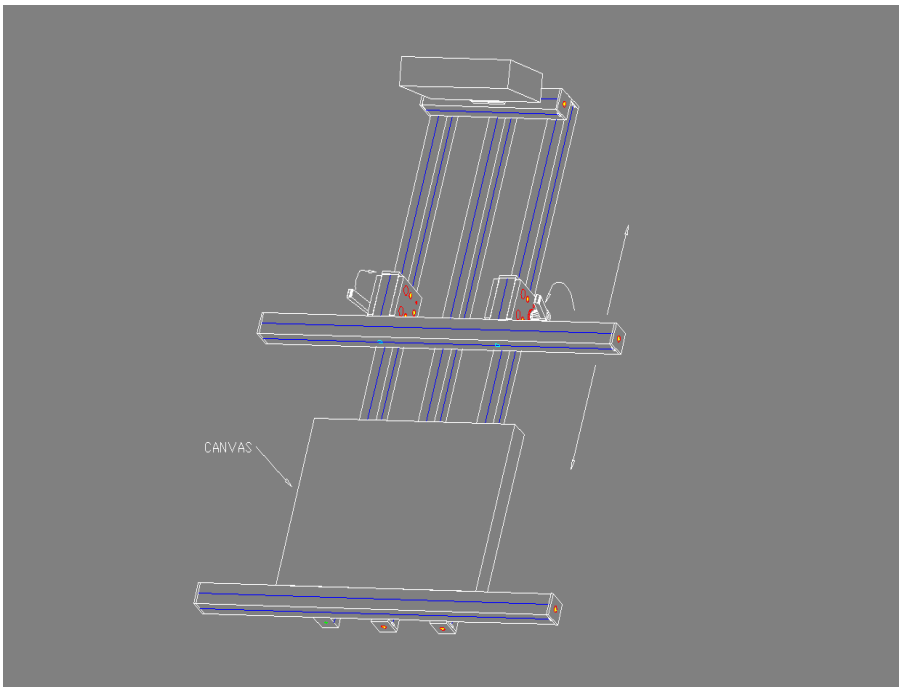
The Canvas holder was designed to accept up to a 20”X24” canvas/art surface. This section of the easel also includes rubber stripping, and when the canvas clamp is used in conjuction with the canvas holder, the painting surface can be inclined so that the artist can paint at an upward angle.



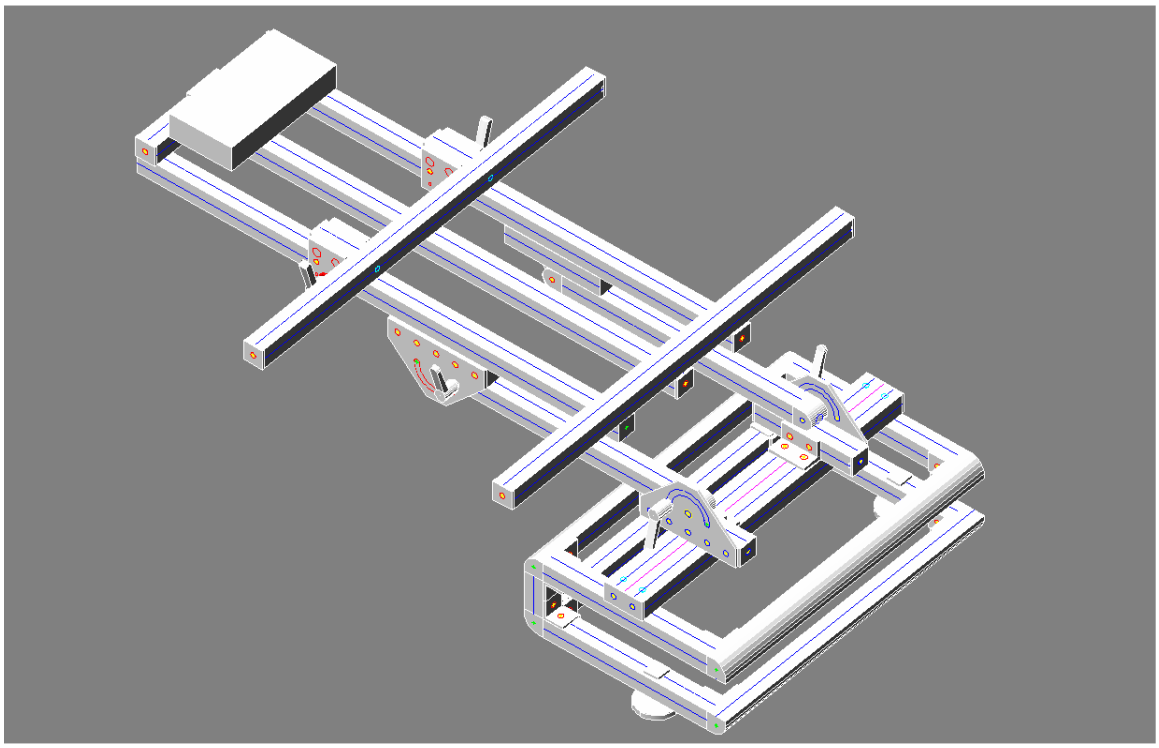
Adjusting the Canvas Holder Height

Canvas Clamp

The sliding canvas clamp is the fourth mechanical part of the easel. It also has rubber stripping which can be used to hold the canvas or other art surface in place. Both the canvas clamp and canvas holder have a slot in the center of the supporting beams where an art surface could be place.



Adjusting the Canvas Clamp



3-Dimensional Rendering of the Easel 5000

Easel Use

The Easel 5000 use is broken down into three major sections. **Adjustment, Attachment, and LED Light Use**.

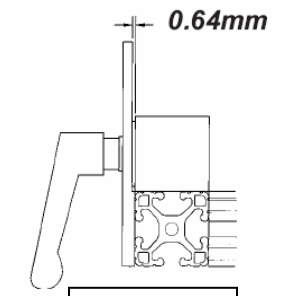
Adjustment

-Adjustment for the easel is controlled by a series of locking L handles.

-When the L handles are rotated and tightened clock wise the handles are in their locked position.

-When the handles are rotated counter clock wise this is the unlocked position.

-When the handles are in their unlocked position this allows the joint that the L handle is located at to be adjusted.

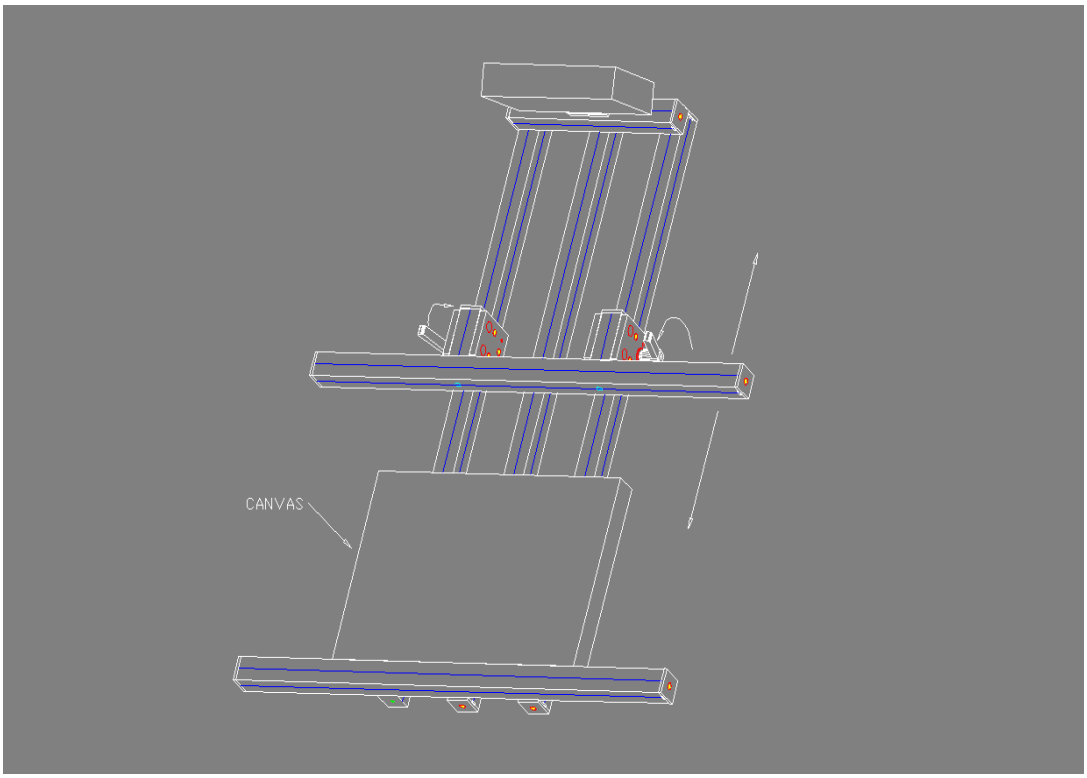


L Handle

Canvas Holder-

-To adjust the canvas holder you must unlock the L handles on either side of the holder one at a time.

-This then frees the holder to slide up and down in order to lock it onto the painting surface.



Using the Canvas Clamp

Adjusting Canvas Holder

-There are slots located in the canvas holder to hold thinner painting surfaces.

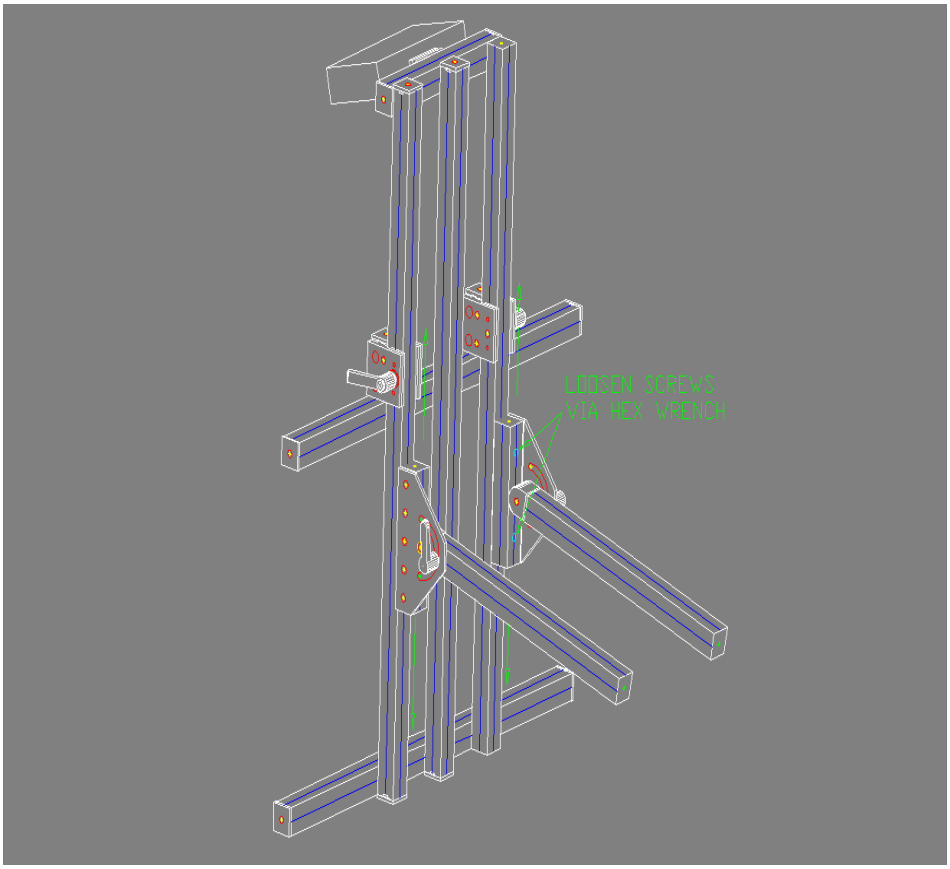
-There is also rubber stripping to hold thicker painting surfaces.

** Additional adjustment of the canvas holder can be achieved with an Alan wrench.

-This adjustment can be preformed as an additional way to adjust the height of the canvas holder.

-An Alan wrench can be used to loosen the bolts that attach the 180 degree pivot to the top of the easel extension.

-Once the bolts are loosened on both sides the pivot can be moved higher or lower on the canvas holder to adjust the height.



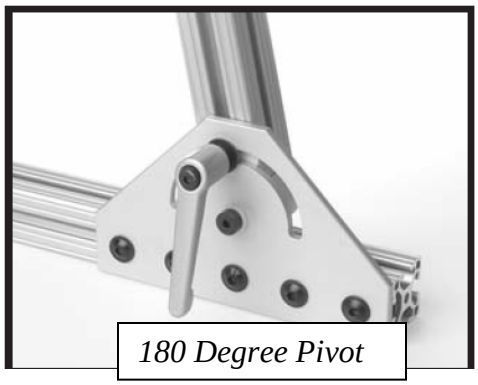
Additional Canvas Holder Height Adjustments

Adjusting Easel Height

-Once the desired height is achieved then an Alan wrench can again be used to retighten these bolts.

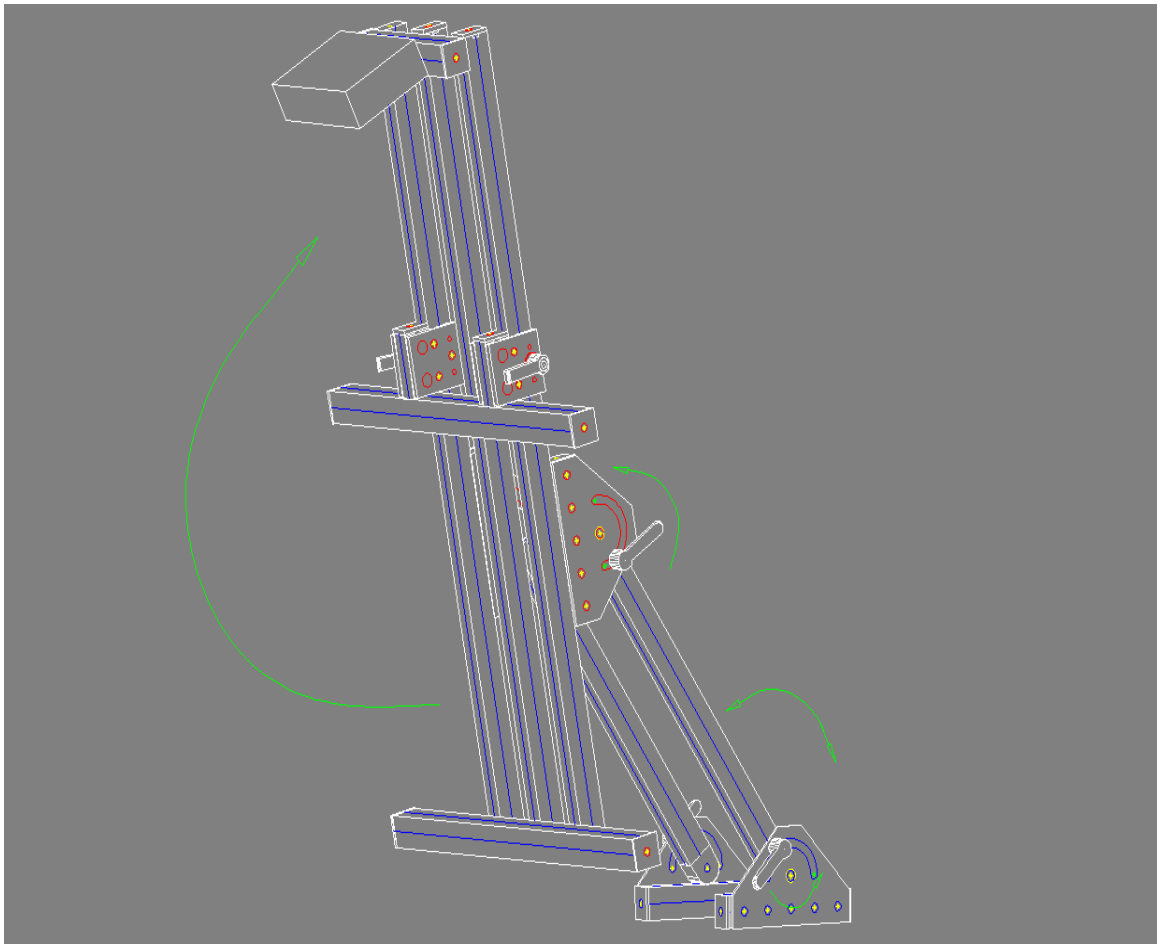
Easel Extension-

-To adjust the easel extension there are four 180 degree pivot brackets. These are located at the point of attachment between the canvas holder and the easel extension and at the point of attachment between the easel extension and the base.



180 Degree Pivot

-These can be adjusted by loosening the L handles one at a time then pivoting the canvas holder on the easel extension or pivoting the easel extension on the base.

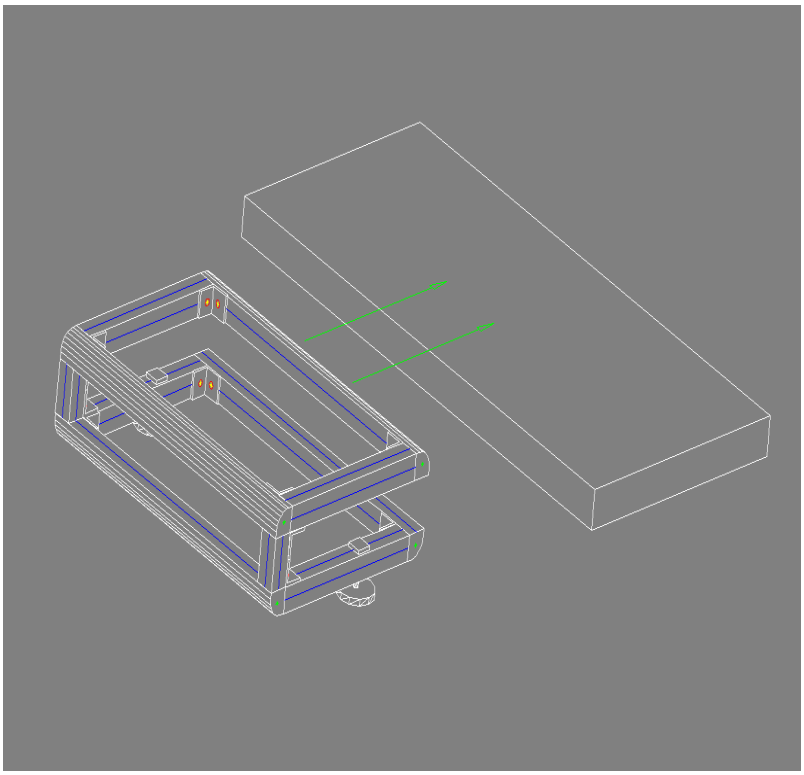


Easel Extension

<u>Attachment</u>-

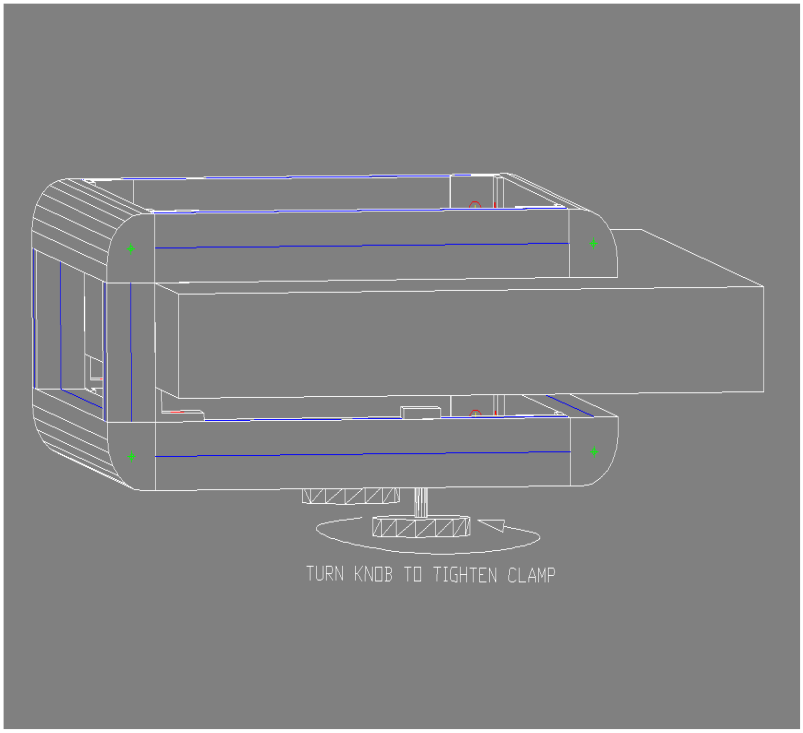
-Attachment for the easel is controlled by screw fasteners located at the bottom of the base.

-The base can be slid onto a wheel chair tray and locked into place by tightening the screw fasteners.



Sliding Base onto Wheel Chair Tray

-This locks the easel base onto the wheel chair tray for use.



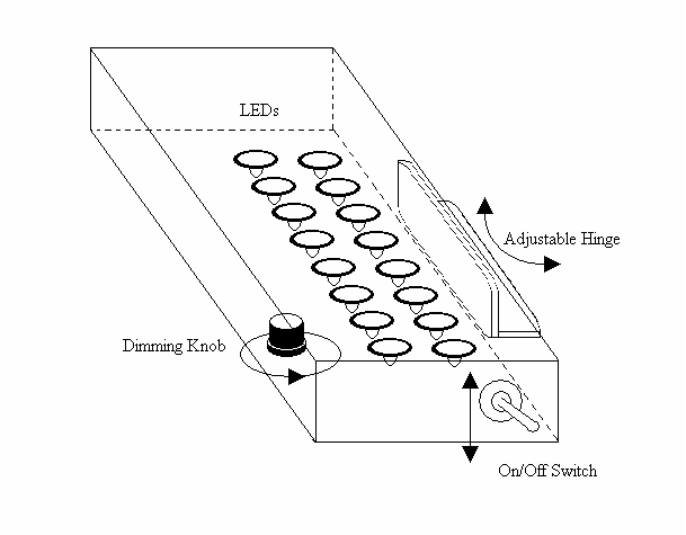
Securing Base to Wheelchair Tray

LED Light Use-

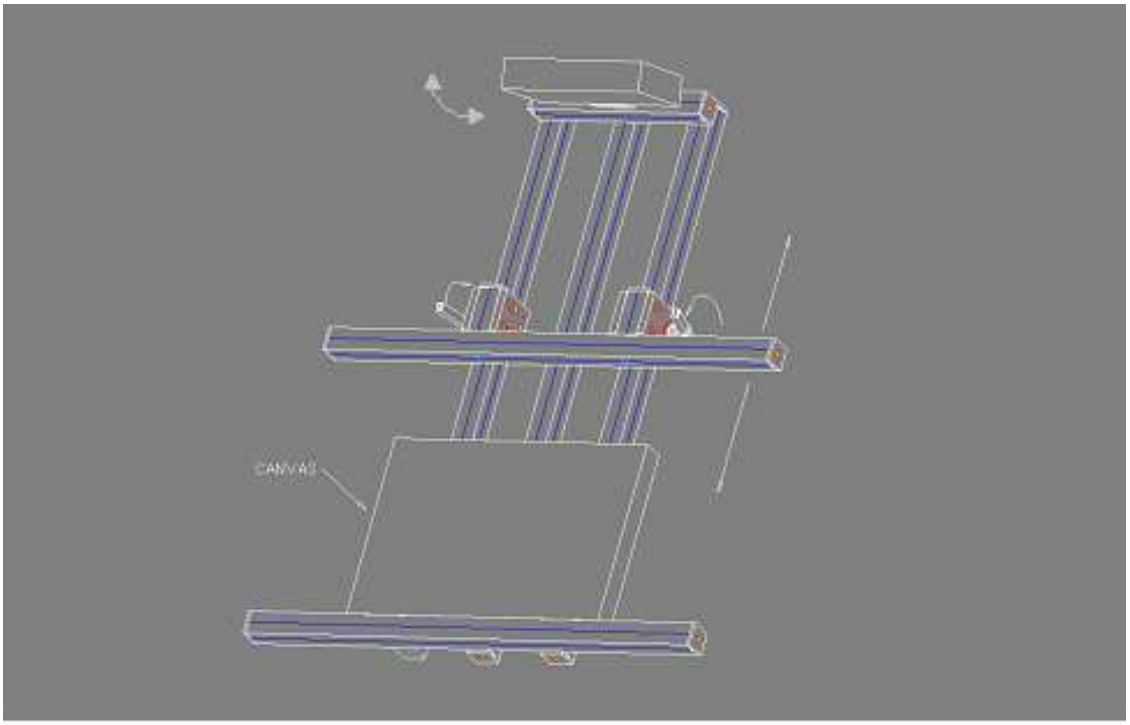
-The LED light can be adjusted up and down via a friction hinge that attaches it to the Canvas Holder.

-The LED light can also be dimmed using the dimming knob located on the underside of the light compartment.

-To turn the light on and off there is an on/off switch located on the right side of the light compartment



LED Light



LED Adjustment

Battery Use-
-To connect the battery line up the red wire of the battery with the red wire of the connector, then line up the black wire of the battery with the black wire of the connector.

-Insert the male end of the connector into the female end of the connector.

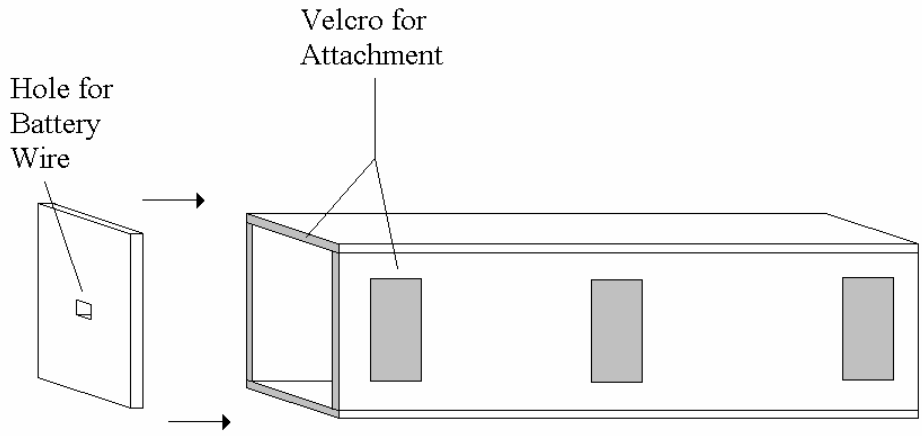
-To charge the battery, remove it from its Velcro plastic box.

-Next line up the red wire of the battery with the red wire of the connector, then line up the black wire of the battery with the black wire of the connector and insert the male end of the connector into the female end of the connector.

-Then with the charger provided plug it into a standard wall socket.

-Charging is complete after approximately 8.5 hours.
-Battery run time with the LED light operating at full capacity is approximately six hours.

Battery Pack for LED Light



Battery Enclosure

12 volt Battery Charger

MAINTENANCE

There are few things that need to be done to the easel for maintenance. The easel is fairly self sustaining and with some regular maintenance it can be kept functional for a very long time. The easel should be maintained on three different time scales. Regular Maintenance, Long Term Maintenance, and Case Specific Maintenance are the three categories of maintenance needed.

Regular Maintenance-

--Battery Source: If the easel is used everyday then the battery source will need to be recharged everyday or every other day. This is a simple procedure that is explained in detail in the *Easel Use* section of the manual.

--Cleaning: Cleaning the easel of paint supplies can be done with a store bought cleaning supply designed for art supplies. Keeping the easel clean will ensure it adjusts properly and the sliding/pivoting motion will be maintained. Try to keep slots in the easel frame free from debris.

Long Term Maintenance-

--Battery: The battery has been designed to have a very long life time, however if the battery has reached the end of its expendable life, than a new 9.6 V battery pack can be purchased. This can be purchased from www.Onlybatteries.com. This will be covered in the table at the end of maintenance.

--Mechanical Function: Not much else can be done to maintain the frame of the easel besides keeping it clean. This will ensure that the joints keep their movement and adjustability. DO NOT OIL THE JOINTS. This will only impede the function of the

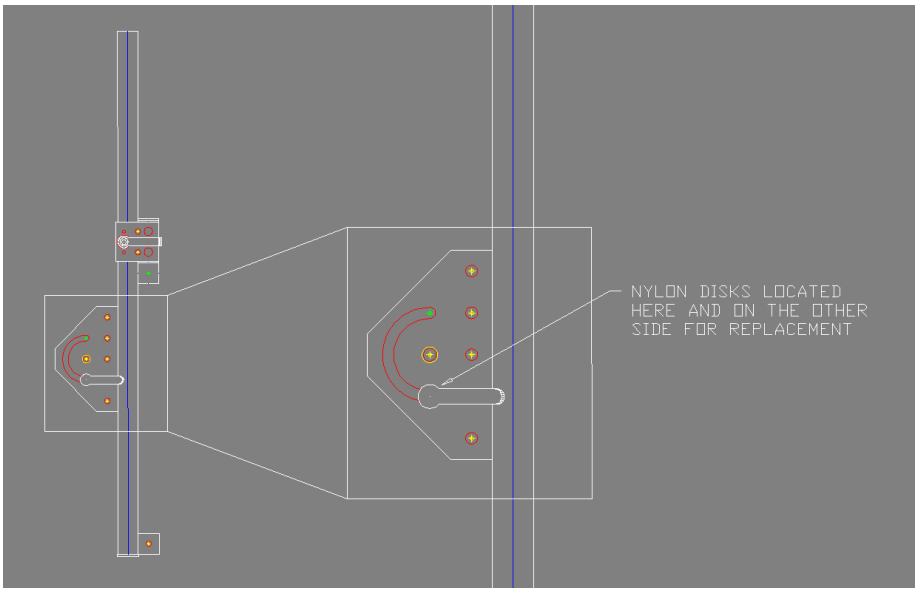
locking mechanisms. These mechanisms function by friction, oiling these joints would remove this friction.

Case Specific Maintenance

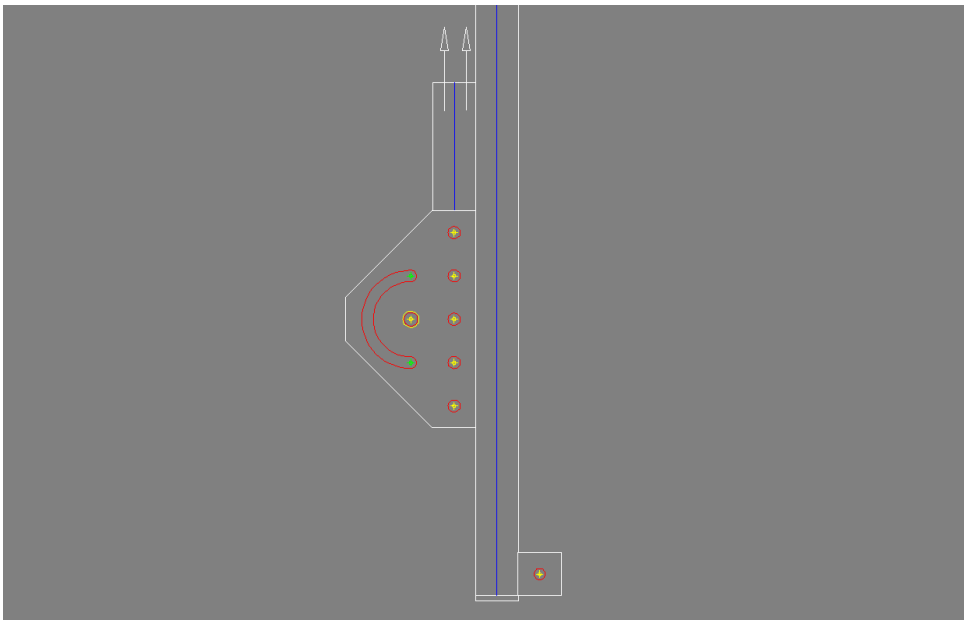
--Components Failure: If any of the mechanical components fail they can be replaced with some very simple tooling from a company called 80/20. Their web site is www.80/20.com. Also refer to the following directions.

In the event that one of the nylon disks at a locking handle needs to be replaced, follow the instructions below:

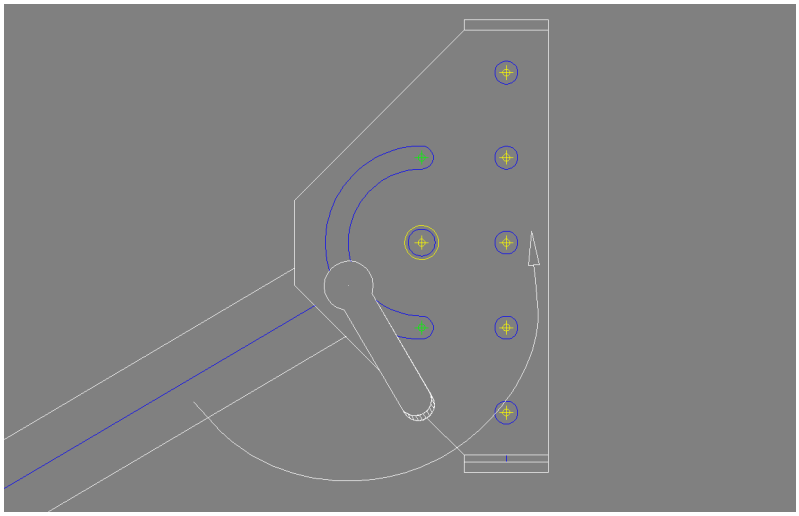
--Remove the canvas holder by loosening the three hex screws on the side of each pivot joint.

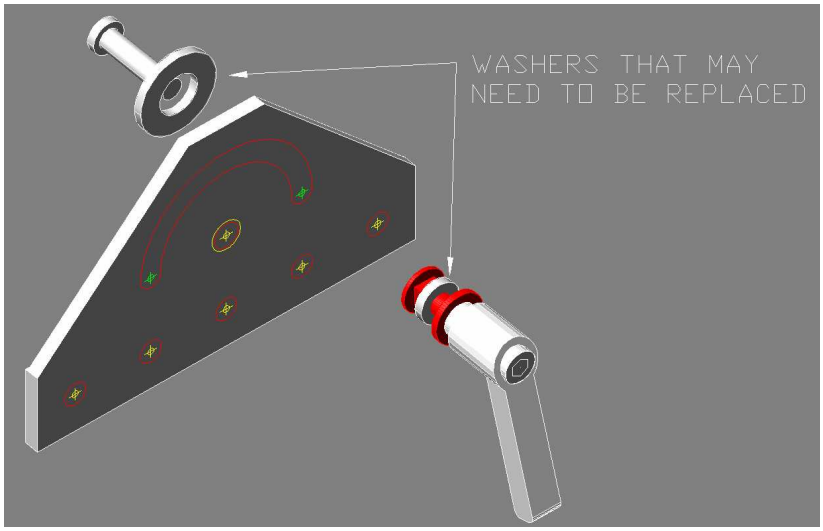


--Slide the canvas holder off the screws.



--Completely remove the L-handle by turning it in a counter-clockwise direction until it comes off. Set the L-handle and any parts that do not need replacing aside.





--Replace the nylon disk(s) on the L-handle assembly and reattach the L-handle to the pivot joint.

-The large nylon washer must be a 1” outer diameter (25.4mm) washer.

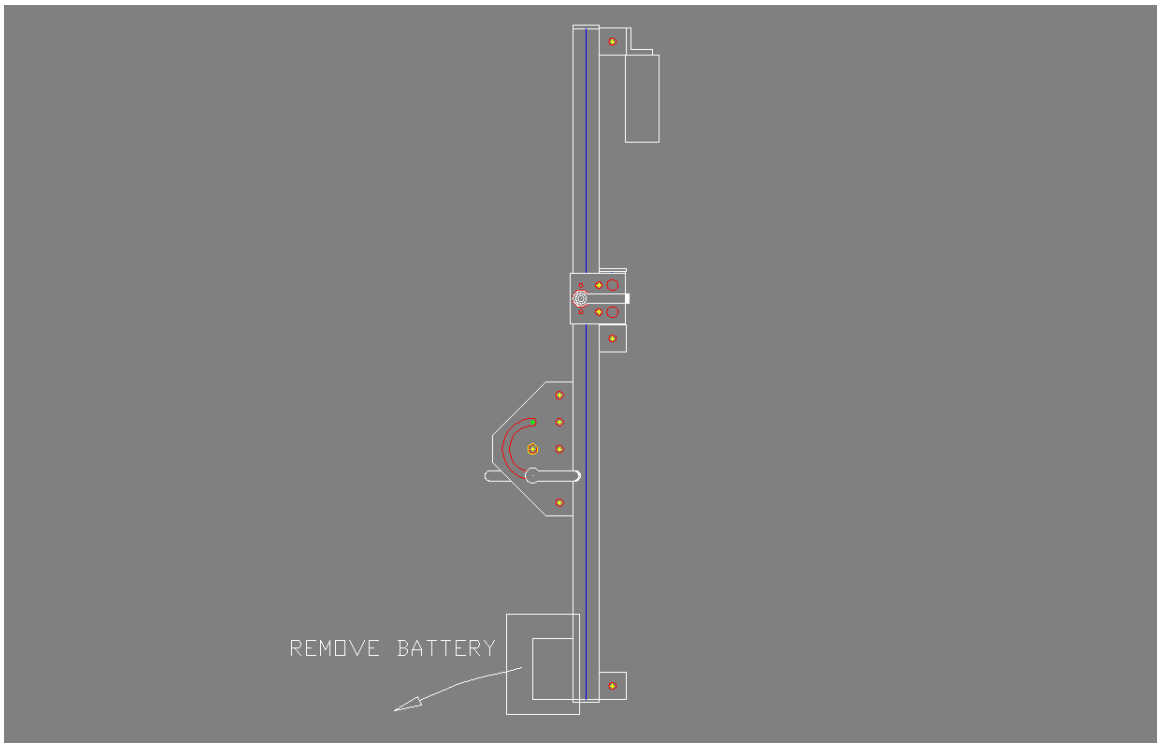
-If the entire L-handle assembly breaks another can be ordered from AIR, Inc. in Framingham, MA or another 80/20 distributor. Part no. 25-2796

--After the part is replaced, reattach the L-handle assembly, and fit the canvas holder onto the two pivot joint assemblies.

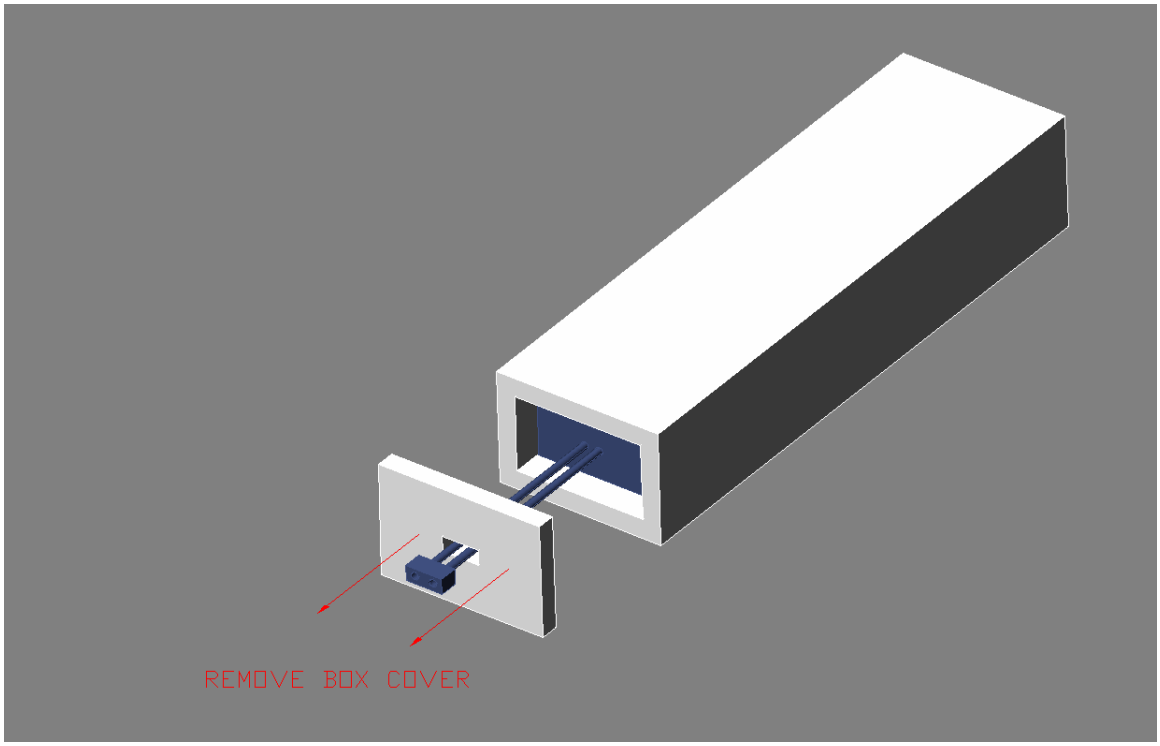
Replacing the battery. (Note: it should not be necessary to replace the battery for quite some time, as it is rechargeable.)

--First, unclip the battery from the wires connecting it to the LED system. The correct clips can be found at the base of the easel.

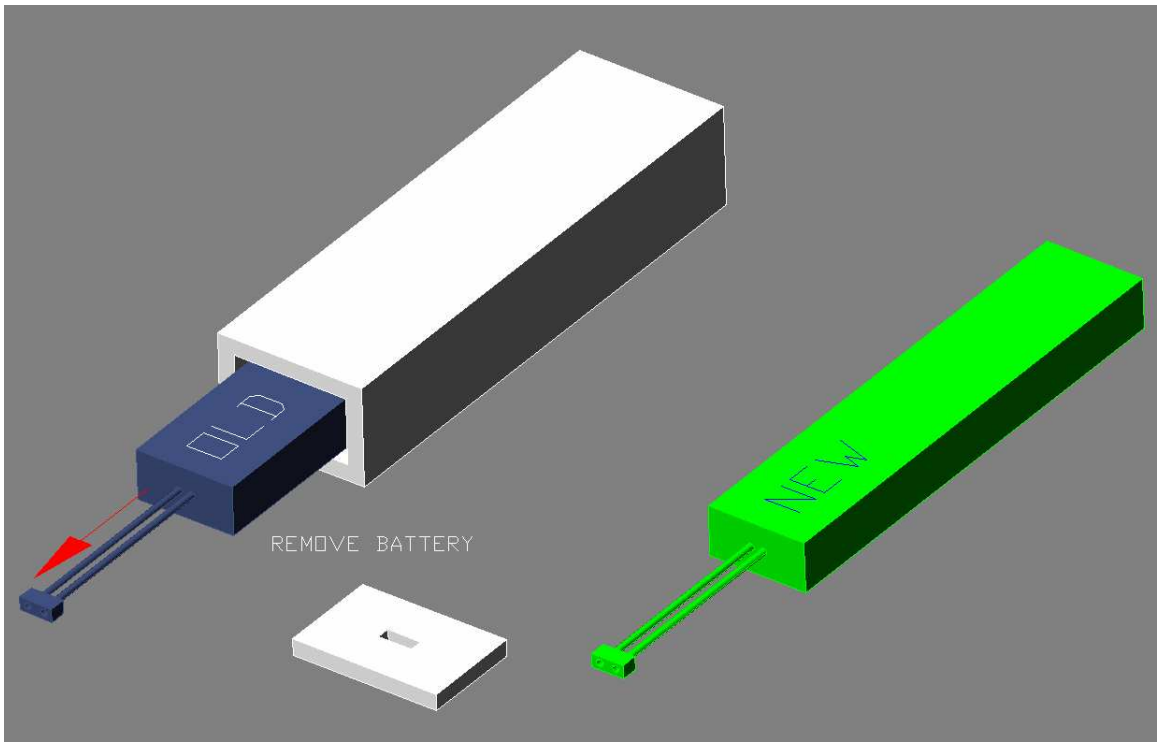
--Take the white battery enclosure off the easel.



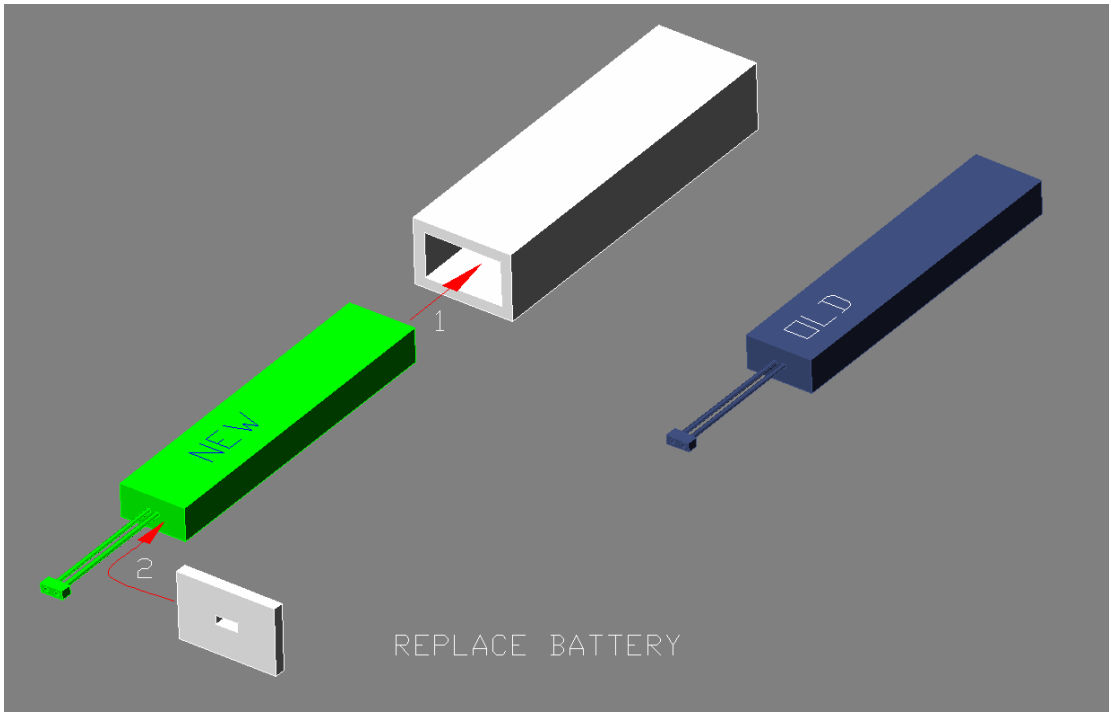
--Remove the top of the white enclosure.



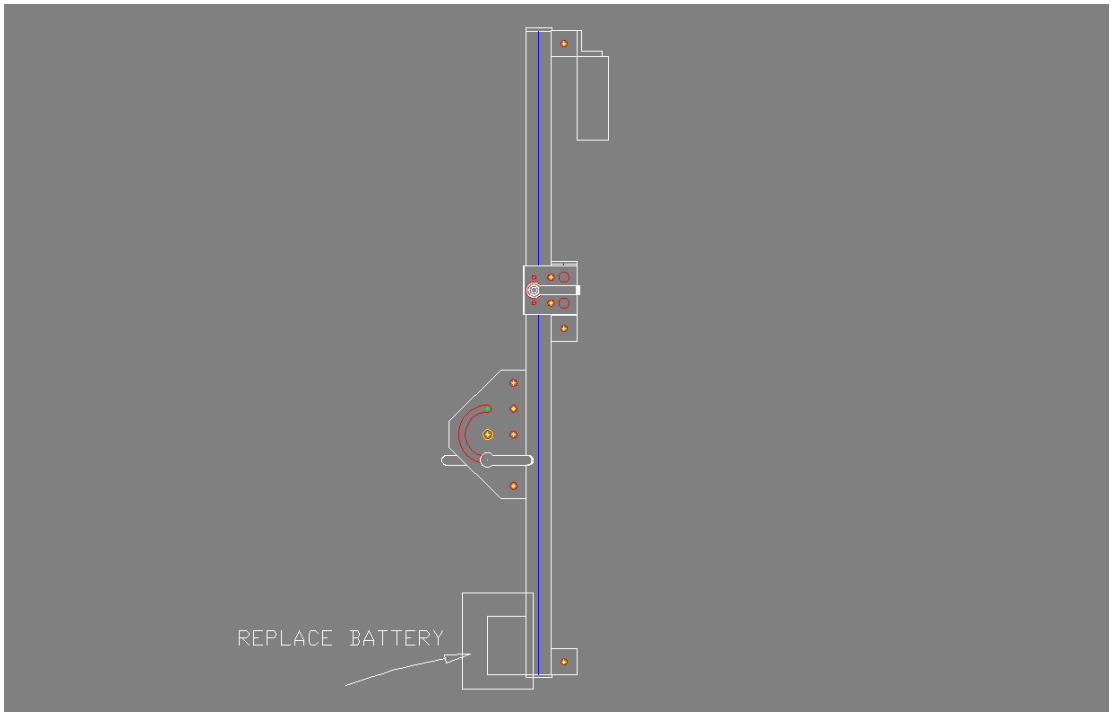
--Grasp the battery and pull the battery out.



--Insert new 9.6V 1700mAh battery into the white casing.



--Replace cap, and put the enclosure back onto the Easel.



Replacing the battery wiring after accidental wire severing.

--**Warning!** Rewiring a battery should only be done by a professional because of a significant shock hazard! Discharge the battery before attempting to replace the wire. If there is no one with experience to do the repair **do not attempt to repair the battery wire**.

Replacing the rubber stripping

--Over time the rubber stripping may wear out and it may become necessary to replace the stripping on the canvas clamp and/or the canvas holder. To do this, follow the directions below:

--Remove the worn rubber stripping; be sure to attempt to remove as much of the remaining glue residue as possible.

--Cut new rubber stripping from a large piece of rubber to 21”x 3/8”. This may require cutting out more than one strip of rubber, depending upon how many rubber strips need to be replaced.

--Fit the rubber stripping on to the canvas clamp or canvas holder.

Replacing the rubber stripping on the easel-to-table clamping device.

--Over time the rubber stripping may wear out and it may become necessary to replace the stripping on the easel-to-table clamps. To do this, follow the directions below:

--Remove the worn rubber stripping; be sure to attempt to remove as much of the remaining glue residue as possible.

--Cut new rubber stripping from a large piece of rubber to 21”x 3/8”. This may require cutting out more than one strip of rubber, depending upon how many rubber strips need to be replaced.

--Fit the rubber stripping on to the canvas clamp or canvas holder. Rubber stripping that has an adhesive surface is the easiest material to use as a replacement solution.

Replacing Velcro stripping on the White battery box.

--Due to repeated removal of the battery enclosure from the easel, the Velcro may weaken over time. Eventually it may become necessary to replace the Velcro to ensure that the battery enclosure remains attached to the easel.

--Remove the battery enclosure from the easel and unhook the battery.
Gently remove the battery from the enclosure.

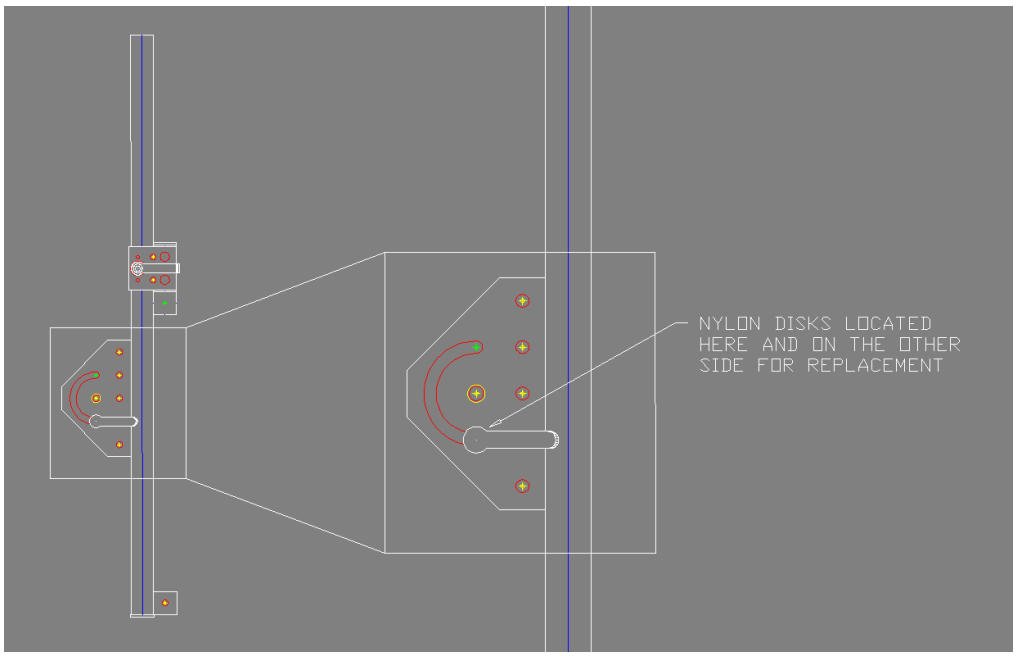
--Using a knife or other cutting tool, carefully remove each of the three Velcro strips from the battery box.

--LED light Failing: If the entire LED light fails it can be replaced by a store bought light. This is the suggested means of replacement. Otherwise the technical description can be referenced for further ideas on how to fix it.

TROUBLE SHOOTING

Although Team Easel 5000 hopes that the use of the easel will be seamless, this trouble shooting section has been included to help the operator or assistant with common questions that may arise. Please note that any repairs to the frame should be done by someone who has had some experience in metalworking/woodworking and repairs to the battery should be done by an individual who has experience in electronics.

- Problem: What if the canvas holder or extension arms move while the locking mechanisms are engaged?
    - This can be hazardous for the user if the problem is not resolved quickly! The canvas holder or the arms can move as a result of several situations:
        - If all the clamps are tightened sufficiently then checking the weight of the material mounted is the next step. Overloading the canvas with too heavy a material may lead to the canvas holder readjusting without any assistance. In this case, the size of the canvas must be changed and a smaller painting surface must be used. Please see the Safety Precautions section.
        - The most common problem may be forgetting to tighten one of the clamps as described above.
        - If the problem persists, check the L-brakes and extension arm joints for damage to the nylon (white) washers. If there is significant damage to the washers or one of the L-brakes, it should be replaced. See the diagram below for the location of the washers and see the maintenance section for details.



- Problem: The battery keeps falling off. How do I fix it?
    - This is usually caused by wear on the Velcro that happens over time. Simply replace the Velcro stripping. See the maintenance section for instructions on how to replace the Velcro.

- Problem: LED lighting system doesn't turn on. What's wrong?
    - Because the lighting system does not turn on does not mean the system is broken.
        - If the LED system is left on overnight or has not been recharged after prolonged use, it is possible that the battery just needs recharging.
            - To fix this simply plug the battery into the charger for 8 and ½ hours to bring the battery back up to full charge.
            - Note: The battery's runtime should be around 6 hours at full charge, so if it is left on by accident overnight, then the battery will be drained.
        - If the battery is fully charged and the LED system still does not work, check the LED enclosure to make sure that no water, paint or other liquid has gotten into the box. It is very important that the LED enclosure not be opened, as a replacement of this particular device is not possible.
        - If the LED box has been deluged with water, paint or another substance, or the circuitry has been disturbed in some way, the damage to the PCB inside may be irreparable. In this case, another light may be purchased online or from a local store and mounted onto the easel.
    - Do not open LED casing as paint, water or other substance may damage circuitry inside and may cause the device to stop working.
    - Do not open the LED casing while the device is on.

- Problem: The canvas is sliding off the easel when the canvas holder is inclined.
    - Usually, the canvas clamp is not securely in place and as a result, the frictional forces usually provided by the rubber stripping is not great enough to hold the canvas in place.
        - To resolve this issue, tighten the canvas clamp onto the frame of the canvas or other art surface. Make sure that the rubber stripping contacts as much of the edge of the canvas frame as possible.
    - Another possible cause is that the material mounted in the canvas clamp is too heavy.
        - In this case, the canvas being used should be downsized.
        - Do not overload the canvas holder
        - Do not place materials larger than 9"X36" or 20"X24" into the easel frame.
        - Do not attempt to adjust the canvas clamping mechanism while the canvas holder is over the artist.
    - The last possibility and most unlikely is that the glue, attaching the rubber stripping to the canvas holder or canvas clamp, could be worn.
        - To fix this problem two options are available.:

        - Glue the existing rubber stripping back on.
        - Buy and cut new rubber stripping as described in the maintenance section.
    - Either option should restore easel functionality.

Mechanical Analysis

Although it was believed that the aluminum extrusion would have no problem supporting the weight of the easel and canvas frame, mechanical analysis was done to verify intuitive suspicions. Below is a diagram of the forces used in calculating the stresses placed on the easel, as well as a table with the mechanical stress analysis results. The forces created by the weight of the easel created a moment of 13.52 N*m about the set of hinges attached to the base. And the appropriate force required to hold up the easel could be supplied by the locking levers.

Weight Calculations

The weights of each individual section were obtained by measuring the unit length (in meters) and then plugging into the following equations:

For lengths of 25-2525:

weight = (Length) * (mass/meter) * gravity
Length is in meters
Mass is in kilograms
gravity is in meters/sec^2
W = L * Mc * g
*W = L * .7443 * 9.81*

For lengths of 25-2527:

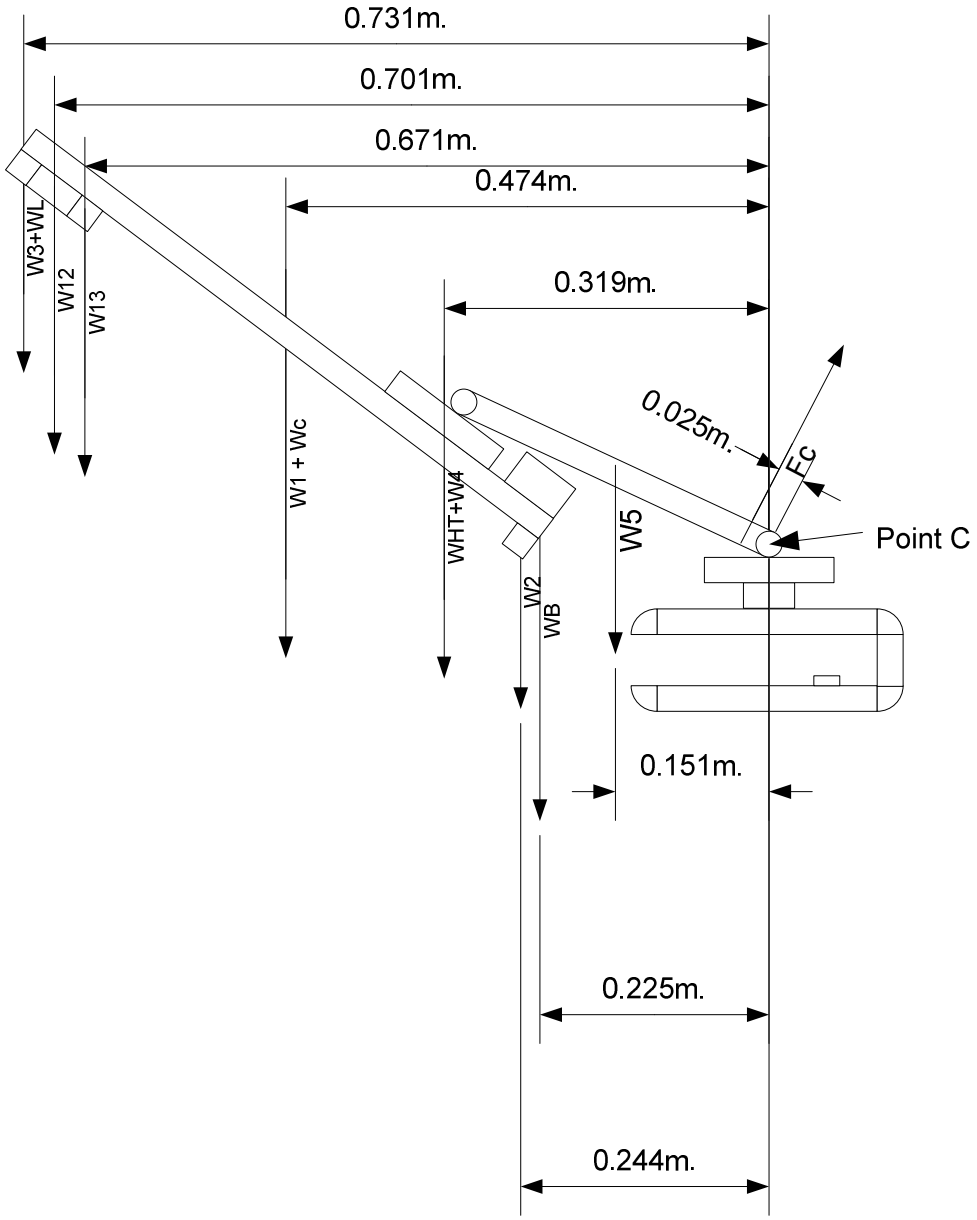
*W = L * .6538 * 9.81*

For lengths of 25-2550:

*W = L * 1.3052 * 9.81*

The table below shows the results of the weight calculations. These results were used in the computation of the bending stresses and normal stresses in respective selected aluminum extrusion lengths and screws that were needed to hold the easel in place.

Section	Total Weight (N)	Number of pieces	Indiv. Weight(N)
Canvas Clamp	6.91	1	6.91
W1	13.91	3	4.64
W2	3.89	1	3.89
W3	1.48	1	1.48
W4	1.85	2	0.93
W5	4.45	2	2.23
W6	1.35	2	0.68
W7	1.85	2	0.93
W8	10.43	4	2.61
W9	6.31	4	1.58
W10	0.74	2	0.37
W11	5.20	1	5.20
W12	2.28	4	0.57
W13	4.64	1	4.64
WL	4.41	1	4.41
WHT	1.35	2	0.68
WB	11.07	1	11.07
total weight (N)	82.13		52.80
total weight (lbs)	18.46		11.87



The diagram above was used to calculate the moment about the first set of dynamic pivot joints at point C. For the ease of calculations, the two pivots were taken as one, and the two easel arms were taken as one.

Moment about Point C			
Section	Wi (N)	Ri/b (m)	Mi(N*m)
W1	13.91	0.474	6.593
W2	3.89	0.244	0.949
W3	1.48	0.731	1.082
W4	1.85	0.319	0.590
W5	4.45	0.151	0.672
Wc	13.34922345	0.474	6.328
WL	4.41	0.731	3.227
W12	2.28	0.701	1.595
W13	4.64	0.671	3.111
WHT	1.35	0.319	0.432
WB	11.07	0.225	2.492
Totals about Point C			27.071
Fc (divided across 2 locking levers	1065.804501	0.0254	27.071

Using the FBD shown in the previous diagram, the moment about point C was found, and from that, the force required to hold the entire easel's weight in the configuration above.

Ff needed		
Variable	Value	Unit(s)
Ff=Fc	1.07E+03	N
Mu	2.50E-01	
Fn	4.26E+03	N

The table labeled Ff Needed shows the calculations for the force necessary on the locking mechanism in order to hold the easel in place with only one locking mechanism engaged.

Stress on the screws			
Variable	Value	Units	Value (MPa)
Stress	1.51E+08	Pa	150.780
P	4.26E+03	N	
A	2.83E-05	m^2	
Assumed Structural steel for yield point (lowest of steels)	4.00E+08	Pa	400

Assuming that the screws used were made of the weakest steel, the stress placed on the screw by the necessary compressive force was calculated. The resulting stress of 150.7 MPa is less than the 400 MPa needed to cause the steel to yield and thus the screws are able to withstand the forces needed to support the easel with only one locking mechanism in place.

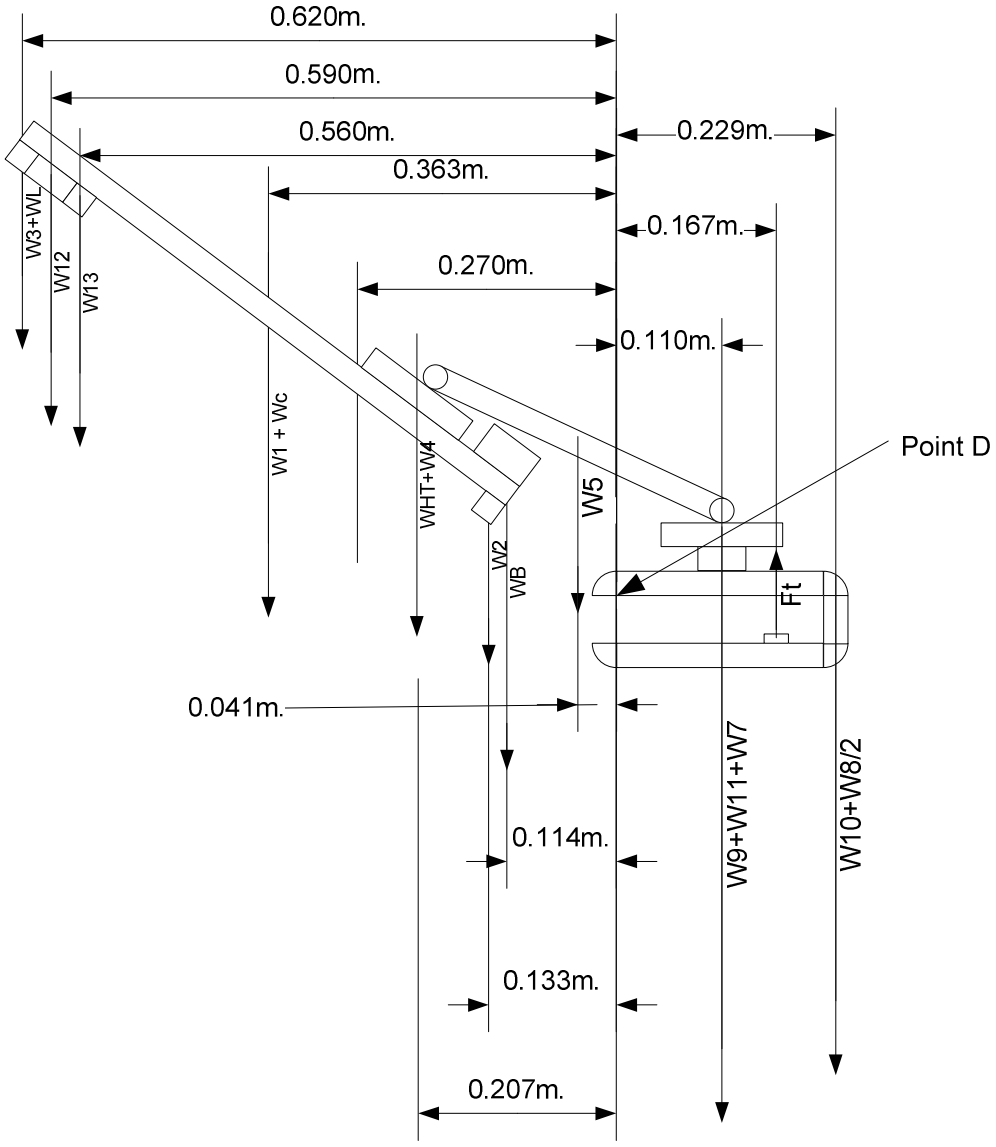
Bending Stresses	Value	Units	Value (MPa)
sigma=M*c/I	1.94E+07	Pa	19.40
M	2.71E+01	N*m	
C	1.27E-02	m	
I	1.77E-08	m^4	
sigma yield strength	1.35E+08	Pa	135

To ensure that the moment caused by the weight of the easel would not cause the aluminum to yield, the Bending Stress calculations were completed. The bending stress found (19.4 MPa) was much less than the 135 MPa need to yield the aluminum.

Note: for the above calculations, mechanical properties were taken from (http://ussautomotive.com/auto/steelvsal/mechproperties.htm) and (http://en.wikipedia.org/wiki/Tensile_strength)

Because one locking mechanism can be used to support the weight of the easel and simulated canvas, the second serves as an equalizer and secondary locking system. This is so that if one clamp is undone, the positioning assistant can make sure he or she has a firm grip on the easel before releasing the second clamp.

Mechanical analysis of the base provided the force necessary to hold the easel in place and secure it to the table. The diagram below shows the forces considered when calculating the moment about point D.



Note: The weights and forces denoted by W and F have Newton's as units of measurement.

Moment about Point D			
Section	Wi (N)	Ri/b (m)	Mi(N*m)
W1	13.91	0.363	5.049
W2	3.89	0.133	0.517
W3	1.48	0.62	0.918
W4	1.85	0.207	0.383
W5	4.45	0.041	0.182
W7	1.85	-0.11	-0.204
(W8)/2	5.22	-0.229	-1.194
W9	6.31	-0.11	-0.694
W10	0.74	-0.229	-0.170
W11	5.20	-0.11	-0.572
W12	2.28	0.701	1.595
W13	4.64	0.671	3.111
Wc	13.34922	0.474	6.328
WL	4.41	0.62	2.737
WHT	1.35	0.207	0.280
WB	11.07	0.225	2.492
Totals about Point C			20.759
Fc (divided across 2 locking levers	124.3071	0.167	20.759

The table labled "Moment about Point D," shows the calculated forces and moments for the diagram above as well as the force necessary to stabilize the easel on the table. This force is labeled Ft.

Stress on the screws			
Variable	Value	Units	Value (MPa)
Stress	4.40E+06	Pa	4.396
P	1.24E+02	N	
A	2.83E-05	m^2	
Assumed Structural steel for yield point (lowest of steels)	4.00E+08	Pa	400

To ensure that the threaded rods bought would be able to function in the role intended, the value of stress was determined. The stress put on the screws (3.30 MPa) was far less thant the yielding stress of the screw's material (400 MPa).

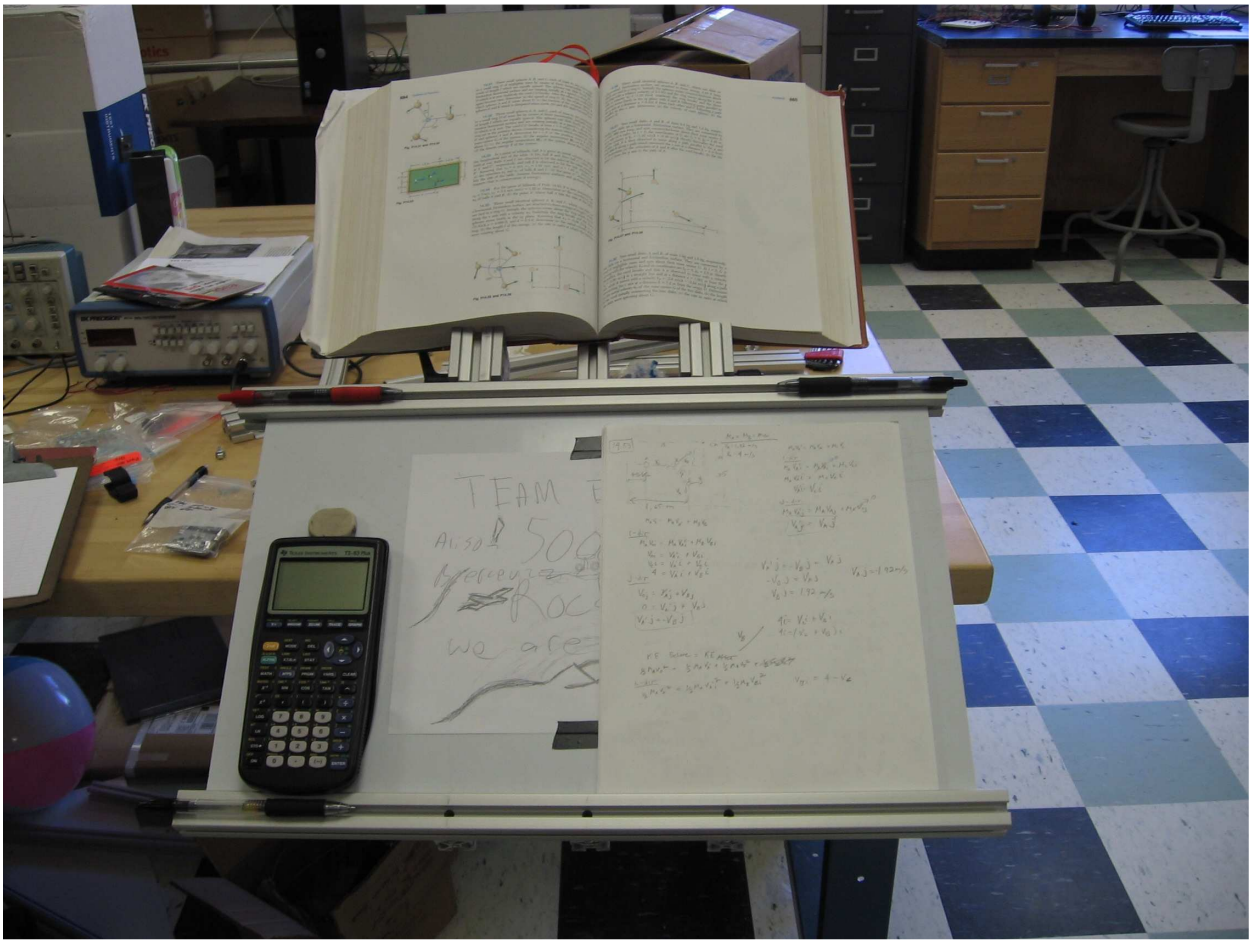
The mechanical analysis showed that the easel would function under normal operating parameters and the secondary locking system, and the easel clamping system would work as well.

PROTOTYPE TESTING

Whenever a prototype is made, testing is an essential part of the construction process. While the Easel 5000 was being constructed, testing was constantly being

done in order to trouble shoot. Testing during construction helped to bring up many problems. During one of the first tests there was a problem with the canvas holder stability. The canvas holder was found to oscillate when hit and create a painting surface that shook. Ideas were discussed to solve this and the appropriate parts were bought and the problem was fixed. This was done by eliminating some of the length of the easel extension and adding an extra arm, thus overall simplifying the design. During a second test, it was found that the sliding track that attached the extension arm to the base was causing a similar stability problem. This was taken care of by simply eliminating the slide. The slide was an unnecessary feature that only complicated the project.

Once the project was completed, additional testing was done to the final product. This was done by loading the canvas holder with a variety of weights and sizes.

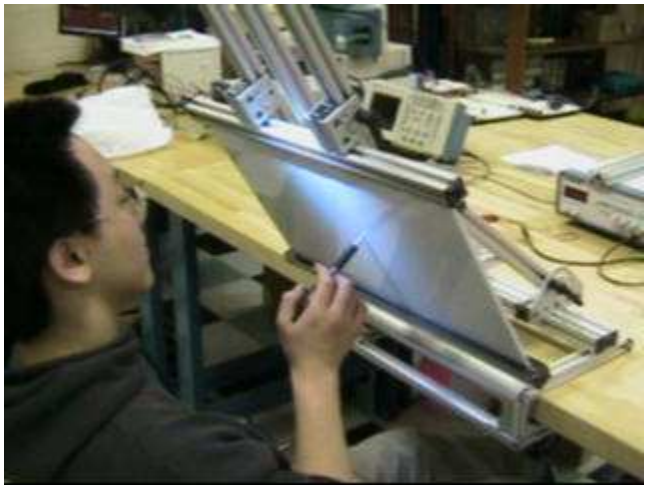


The Easel 5000 Shown Holding Various Items Including A Textbook

Also it was used as a writing surface to ensure it could handle the similar motion of painting. Then the adjustability was tested. The easel was tested at a variety of heights to make sure it could accommodate many artists. Then it was tested to make sure it could reach the height of a wheel chair. Finally it was tested with a subject that pretended to have cerebral palsy. This showed that even with a limited range of motion a user could reach the painting surface with ease. The base was then tested to make

sure it could handle the moments created by the easel extension. This was also proven successful.

The following series of pictures shows the testing that took place for the Easel 5000.



The final bit of testing was done on the LED system, which can be seen on in the last picture provided above. The battery was tested to see how long it lasted in the system and how long it took to charge. The battery lasted roughly six hours at its highest setting. It also took eight hours to charge to its full capacity. Finally the LED system was checked to make sure the dimming knob as well as the on/off switch were fully functional.

In conclusion, testing was an essential part of the prototype building process. This allowed us to trouble shoot and solve problems with the easel. Also it allowed us to find the constraints on its use. These things are all very critical to the easel's use.

3 REALISTIC CONSTRAINTS

3.1 Engineering Standards

When designing and constructing any prototype it is important to take engineering standards into consideration. Engineering standards vary by application but in general they apply to the technical, structural, and quality standards of a product. These standards are important and make sure the product is safe for use. These standards were very important when designing and constructing the prototype for the Easel 5000. When designing the Easel 5000 it was important to take into account technical, structural, and overall finished quality. We wanted to make sure that technically the easel fulfilled its specifications set out for the project last semester. Things like adjustability, locking joints, canvas weight, and a light source were all things that had to be considered. Structurally the easel had to be sound. It had to support a canvas of vary weights sizes and materials. Also it had to with stand regular use and be easy to use. While making the easel functional was the main goal of the project aesthetics also had to be considered. The easel had to look professional and finished. Machining and tooling had to be done carefully in order to ensure clean lines on the product and a finished look. Also much forethought had to be put into many of the components to make sure the final product didn't have any visible mistakes. Taking engineering standards into consideration really took the project from simply functional to complete and professional.

3.2 Economic

As mentioned, the funding allotted for the project is a maximum of $750. This budget will need to cover all aspects of the easel. Examples of necessary budget expenditures are raw materials, machine shop welding, troubleshooting, and packaging. Overall, the finished product of the Easel 5000 will strive to be affordable to the public. With efficient design, the easel will have a lower cost than many commercial products to date with similar or competitive features.

3.3 Environmental

The finished product of the Easel 5000 will be composed of nontoxic materials. The only materials used for the easel will be aluminum, rubber, plastic, and steel. The process of designing and constructing the easel will be environmentally safe. The majority of the easel is constructed of aluminum. That being the case, the project can be easily disposed of in an environmentally friendly manner. By removing the non-aluminum pieces, the aluminum components may be brought to the nearest recycling center for future use. The other steel components may be recycled as well and the other smaller components should be disposed of.

3.4 Sustainability

Maintenance for the Easel 5000 will be minimal. Although aluminum is very corrosion resistant, the easel will be painted, thus further reducing possible corrosion. With moderate use, the easel maintenance could consist of oiling joints to reduce friction and squeaking. Bolts may need tightening on occasion and rubber strips may need adhesive reapplied.

Repairs to the easel may be made by replacing any damaged parts. The easel will include an operating manual addressing these parts. This manual will be included in the packing contents. An approximate estimate for the lifetime of the easel will be five years, in which the device might fail due to fatigue and general wear. However, the non-metal components of the design will likely need to be replaced before five years of use. These parts include LED lights, wires, batteries, bolts, washers, and paint.

3.5 Manufacturability

Easel 5000 will be manufactured on the University of Connecticut campus in the certified machine shop. Aluminum is an easily machined material and thus was highly considered as the usable metal for easel components. The optimal design includes dimensions and details on each subunit within the easel to make effective future reproductions of the Easel 5000.

3.6 Ethical

No animals or people will be hurt in the construction or design process of producing the final product of the Easel 5000. Commercial copyrights and patents have not been and will not be violated with the construction or design of this adjustable easel. Commercial products and patents are discussed in another section.

3.7 Health and Safety

The Easel 5000 warrants no outstanding health risks. However, there are a few

items to be cautious of when dealing with. If the wire from the lighting source to the battery is exposed or damaged, be sure the on/off switch is set to the ‘off’ position before handling with the exposed wire. Be sure the on/off switch is in the ‘off’ position when replacing battery.

The easel is designed to reduce as many safety concerns as possible. The elimination of easel legs facilitates wheelchair users. The light source has no cord to plug into an electrical outlet. Both the lack of easel legs and the cord highly reduces the likeliness of a tripping hazard when dealing with the easel. The finished easel will have rounded edges so that the users will not get hurt on the corners. In addition, there will be no exposed wires to ensure higher safety.

3.8 Social

The development of the Easel 5000 is to aid in people with disabilities. Main areas of concern socially are how well the artists with cerebral palsy are able to maintain their art in a comfortable environment and ease of use of this easel. Although many of these artists may have abnormal muscle tone and movements, they are still very talented. The designed easel needs to be easy enough to use, while giving the artist a nice interface so that they could paint however is most comfortable for them.

3.9 Political

The Easel 5000 was made possible by the National Science Foundation. A budget of $750 was provided by the foundation that paid for all of the associated costs for the design and construction of the easel. The NSF is a government funded organization that “promotes and advances scientific progress in the United States by awarding grants and agreements for research and education in the sciences, mathematics, and engineering (NSF)”. Because Easel 5000 is part of an NSF project it is part of the advancement of technology in the United States.

4 SAFETY ISSUES

Safety is an important concern for any project. For the Easel 5000, safety considerations for environmental, mechanical, and electrical hazards were evaluated. The procedure began by generating a list of malfunctions and or errors in operation that could take place.

With the easel, the primary area of concern was on the functionality of the locking mechanisms and joints. The results of not engaging a locking mechanism or not taking care when positioning the device could result in injury to either the artist, the assistant, or both. To avoid these injuries warnings were included in the safety manual specifically stating common errors and situation to avoid when using the easel. The following is a list of items generated to account for the mechanical safety of the artist and assistant.

- Pinching hazard at dynamic pivot joints
    - Warnings included in the manual
        - WARNING: Pinching hazard at joints
    - Recommendations for avoiding the situation described
        - Be sure that fingers are clear of any moving joint before adjusting the easel. Only after fingers are clear of joints should one adjust the easel
        - There is also a list of joints in safety manual where there is a pinching hazard.
            - The four 180 degree pivots
            - The L brakes on the canvas holder
            - Adjustable friction positioning hinge for the LED light
            - Base fasteners
- Canvas Holder section may fall on the user
    - Warnings included in the manual
        - WARNING! Canvas holder may fall on user!
    - Recommendations for avoiding the situation described:
        - Be sure to tightened both locking handles at one joint before letting go of the easel after adjustments have been made.
        - Only loosen one L brake at a time
        - Only let go of the easel after both sets of L brakes have been tightened securely.
        - Make sure both L brakes are tightened securely after adjustment is finished.
        - When adjusting the canvas holder make sure to adjust one L brake at a time to avoid loosing control of the easel
        -
- Canvas or other painting surface may fall out of the canvas holder
    - Warnings included in the manual
        - WARNING! Canvas may fall on user!
    - Recommendations for avoiding the situation described:
        - Check to make sure that the canvas clamp rubber stripping contacts as much of the canvas frame as possible.
        - Check that the canvas clamp is securely fastened and that the canvas clamp locking handles have been tightened.
        - Do not overload canvas holder Do not place materials larger than 9”X36” or 20”X24” into the easel frame.
        - Do not attempt to adjust the canvas clamping mechanism while the canvas holder is over the artist.
        - Do not attempt to adjust the canvas clamping mechanism while the canvas holder is inclined forward.
        - Make sure to retract the easel extension before adjusting canvas clamp.
        - Use slots in the canvas holder when ever possible when mounting a canvas.
        - Avoid Canvas weights in excess of ten pounds.

        - Make sure that both sets of locking mechanisms engage for canvas loads of over 3 pounds.
- Easel may slide off the table or become dislodged.
    - Warnings included in the user's manual:
        - WARNING! Do not use the easel if the base is not securely fastened to the surface it is mounted on.
            - Failure to secure the base to the surface it is mounted on can result in the easel falling on the artist
        - Make sure both fasteners on the base are secured to its mounting surface before use.
- Velcro wear may cause battery to fall off easel and onto user
    - Warnings included in the user's manual:
        - WARNING! Abuse of Velcro on Battery compartment can cause loosening of battery.
    - Recommendations
        - Avoid abuse of battery compartment and Velcro
        - Replace Velcro when Battery compartment appears to be unstably attached.

These safety recommendations were effected so that the user and adjuster could operate the easel without risk of injury from mechanical actuation of the easel if the guidelines are followed.

The second set of factors was environmental concerns. While the easel is made of aluminum, which is a rather robust material for the application, certain environmental factors encountered during use could put the user and easel in jeopardy. To account for environmental hazards the following items were considered.

- A large external force may be applied to the easel
    - Warnings included in the user's manual:
        - WARNING! DO NOT PLACE EXCESSIVE FORCE ON THE EASEL!
    - Recommendations:
        - Do not use the easel for holding objects other than art paper and canvases.
        - The easel may be used to hold sheets of metal within the specified weight range of 3 -10 lbs.
        - DO NOT USE THE EASEL TO SUPPORT A PERSON'S WEIGHT
        - DO NOT HANG OR LEAN ON THE EASEL
- Looking directly into the LEDs may cause temporary disorientation and pain.
    - Warnings included in the user's manual:
        - WARNING! DO NOT LOOK DIRECTLY AT THE LED LIGHT
        - Looking directly at the LED light for an extended period of time can cause damage to the eyes.
    - Recommended use guidelines to avoid situation:
        - If adjusting the LED light dim it or turn it off first
        - Do not intentionally shine the LED system in the eyes for an extended period of time.

        - Before turning the LED system on, be sure that the LEDs are not pointed at the face of the user or any bystander.

The third factor accounted for in the safety manual was that concerning electrical hazards. Although all the wiring, power source, and circuitry are enclosed and insulated, there are certain conditions of operation that would prevent the user from getting injured.

- It was thought that a general warning was important and so that was included in the manual.
    - WARNING! Product CONTAINS ELECTRICAL COMPONENTS!

Other situations that may arise were thought of ,and appropriate warnings were created to give the operator guidance when using the easel.

- Shock hazard
    - Recommendations to avoid being shocked by the battery:
        - Keep LED light enclosure closed at all times. DO NOT OPEN THE LED LIGHT UNDER ANY CIRCUMSTANCES
        - Keep water away from the LED light.
        - Keep paint and other painting supplies away from the LED light.
        - Keep water away from the battery compartment.
        - Keep paint and other painting supplies away from battery compartment.
- Similarly, to keep the battery from shorting at the connectors, the following guidelines and warnings were put in place.
    - Recommendations to prevent shock and shorting due to battery connector and lead problems:
        - Keep water away from the battery connectors.
        - Keep paint and other painting supplies away from the battery connection.
        - When recharging battery first connect the battery to the charger, then plug the charger into the wall socket
            - DO NOT PLUG IN THE CHARGER FIRST, THEN CONNECT THE BATTERY!
        - DO NOT CUT ELECTRICAL WIRES.
        - DO NOT TAMPER WITH ELECTRICAL WIRES OR COMPONENTS.
        - DO NOT INTENTIONALLY SHORT THE BATTERY. DOING SO WILL CAUSE THE LEADS AND THE BATTERY TO HEAT UP WHICH CAN CAUSE BURNS.
        - Do not disassemble the canvas holder as the frame contains electrical wiring.

- Warnings for the operation of the LED were also included in this section as well.
    - Warnings included:
        - WARNING! DO NOT OVER ADJUST DIMMING SWITCH ON THE LED LIGHT.
    - Recommendations for correct operation:
        - Do not attempt to turn the dimming switch past one full turn

The preceding information was thought an adequate guideline for reasonable use of the easel and the lighting system. Some specific conditions were outlined and appropriate recommendations were made to avoid injury to the user and bystanders, as well as prevent damage to the easel.

5 IMPACT OF ENGINEERING SOLUTIONS

Easel 5000 will ultimately have a large impact. Tom is a 44-year-old man that has cerebral palsy, dysarthria, moderate cognitive impairment, visual acuity trouble, limited dexterity, and limited arm movement. Because of his disabilities many tasks become much more difficult. One of Tom's favorite hobbies is art. His artistic endeavors include poetry, sculpture, and he specializes in acrylic painting. Passion works has given him an outlet to practice his craft. Unfortunately passion works had difficulty supplying Tom with a device for painting that was sensitive enough to his needs. Team three has been given the chance to design and construct an easel specifically for Tom. Now Tom will have a means to paint and do what makes him happy more easily. When discussing the project with Patty Mitchell, the Passion Works art coordinator, it became obvious how important this easel would be for Tom. She discussed how close her relationship with Tom was and how much she wanted an easel that would make painting easier for him. After discussing our project with her further she gave us a better idea of where the design and construction should head. All of the input from Patty was put to good use when putting together the easel. Patty was emailed pictures of the final product and she was ecstatic. She seemed hopeful that our project would be the right fit for Tom. This easel will really make a difference in Tom's life. Because Passion works is a globally reaching program Tom's new found ability to paint will reach many people. His paintings have previously been shown and sold in galleries for increasingly high fees. The Easel 5000 will make this reality much easier. Tom's income from his paintings will help further himself and his program economically, hopefully reaching out to other people with similar artistic passion.

"Big Headed Girl" by Artist Tom Depugh

6 LIFE LONG LEARNING

The project was not just about making an end product it was also meant to be an introduction to industry experience. While this experience can't be expected to exactly mimic an industry experience it was definately a good introduction. As a team we learned how to develop, organize, and design a project. This involved tons of calculation, communication, research, and brainstorming. By the end of the first semester we had gotten very good at this due to the fact we had to independently design four separate designs. This was all done in the first semester and was a great experience but offered little hands on work. Second semester offered a chance to really get experience putting something together. As a team we had to achieve our individual goals and then integrate them for the combined project. This took a lot of team work and communication. As a team we had to learn how to respect each other's space and work. We also had to learn how to lend a helping hand when needed. Each member had a chance to learn something new during the project. We all got experience crafting something and working with tools. We all were also exposed to dealing with industry or suppliers through the acquisition of products that we manipulated for the project. Also new programs were learned to help advance the project.

In all this project and course has offered up a great opportunity to broaden our experiences. We have all experienced something new and had to deal with frustrations and problems that ultimately had to be solved. This was an excellent experience and we all gained life long skills that will be used many years down the line in our careers.

7 BUDGET

Managing a budget is never easy, especially when creating a prototype. When designing and constructing a prototype a general idea of where the project is going is always in mind but it is hard to keep track of details. This results in an uncertainty of what is needed in the budget. There are always last second things that need to be bought and accounted for in the design that one could have never predicted. Also components that were thought to be essential end up not being used and need to be returned. Another consideration with budget are the items that are not tangible. Shipping costs and return fees ended up playing a big factor in our budget. This was due to the fact many of our items had to be returned and incurred shipping costs. Also many of our items were heavy and or large and required special shipping and extra charges. Lastly some last minute additions were made to the budget. Some products had to be order to put the finishing touch on the project and also a PCB was an added requirement and that added substantially to the budget. However our group saved a lot on budget as well. Many items were received as free samples or at a discount from willing companies.

Costs

Date	Vendor	Cost	
		Debit	Credit
1/5/2006	LED Supply	36.25	
1/9/2006	McMaster Carr	142.86	
1/20/2006	McMaster Carr (returns)		133.76
1/20/2006	McMaster Car shipping on return	18.97	
1/31/2006	Air Inc (80/20)	497	
2/13/2006	Air Inc (80/20) (returns)		84
2/13/2006	Air Inc shipping on returns	26.03	
1/31/2006	Modern Plastics	30.97	
2/14/2006	Jameco	4.01	
2/14/2006	Onlybatteris.com	37.74	
2/16/2006	Air Inc (80/20)	63.75	
3/7/2006	Digi Key	11.42	
3/20/2006	Air Inc (80/20)	29.2	
3/22/2006	Mansfield Supply	10.91	
3/27/2006	Air Inc (80/20)	25	
4/1/2006	PCB Express	99.87	

Total Spent	Total Credit
1033.98	217.76

Total for Project (with credit)
816.22

Allowance made by Professor Enderle

PCB	99.87
End Caps	25

Total Allowance
124.87

Total - Allowance
691.35

Free Samples and Discounts				
Company		**Discount**	**Samples**	
Onlybatteries.com		20% off		
LEDtronics			Free LED panel mounts	
Reell Incorporated			Free Friction Positioning hinges	
OKWenclosures			Free Plastic Enclosures	
Hammond Manufacturing			Free Plastic Enclosures	

In conclusion with the NSF budget set at $750 the money spent on essential parts of the projected totaled $691.35 which is under budget. If the PCB and end caps are factored in the budget reaches $816.22. While this is over budget these last second additions to the budget were allowed by Professor Enderle to finish the project correctly. The budget allocated by the NSF was definitely substantial but if we had been more familiar with shipping and return costs the entire project could have been done for the NSF allocated budget.

8 TEAM MEMBER CONTRIBUTIONS

8.1 Alison Biercevicz

The main part of the project that Alison worked on was the LED lighting system. This required a large amount of work. This included much research on LEDs, timing chips, circuitry, batteries, and production methods. Many different designs had to be gone through in order to include the dimming option and prolonged battery life. PCB schematic and PCB express were two programs that had to be learned in order to design and order a printed circuit board. This also involved a trouble shooting. A great deal of time was also spent keeping up with contacts and ordering to ensure the right parts were being ordered and free samples were being received. In the last part of the

semester time was also spent in the machine shop helping Seth with final machining for the easel frame and LED enclosure. The last two weeks involved extensive construction, soldiering, and trouble shooting with the PCB board. In all a lot of basic skills for problem solving, team work, and communication were learned along with some very specific skills for dealing with machining, PCBs, and LEDs.

8.2 Seth Novoson

Seth's main job throughout the semester was machining the parts necessary to assemble the easel. Although parts were easily attained and usable from 80/20 Corporation, these parts still had to be cut down to size. In addition, holes needed to be drilled, edges de-burred, extrusion ends thread tapped, and various other tasks that could only be accomplished by Seth since he was the only member of the team that was machine-shop certified. For mechanical analysis purposes, looking at stresses and determining forces applied throughout the easel design was completed. This analysis was especially important to determine that the easel could function not only in ways that a normal easel could, but also when the easel was adjusted in extreme positions unlike other easels. The mechanical analyses completed were all documented and kept track of in excel format for computerized calculations. When any design changes occurred, this documentation was constantly updated. Finally, contributions to reports were made with various Microsoft Visio drawings.

8.3 Justin Yu

In the beginning of the semester, Justin mostly helped out Seth at the machine shop to prepare all the pieces needed before easel construction began. At this time, the mechanical calculations were examined and rechecked since they were very important to ensure that the easel design could work. When all the pieces arrived, Justin was the main member in charge of easel construction. Time management for the project was handled on a weekly basis to keep track of how far along the project each process needed to occur. With the LED system, after the PCB schematic was completed, many designs had to be made. In order to fit the LEDs in correct places and fit the PCB itself into the correct size encasement, the PCB design was adjusted numerous times. When the PCB came in, Justin was in charge of soldering components onto it. For documentation and reports, CAD drawings seen in this report were completed by him. These drawings took a lot of time since 3-dimensional CAD had to be learned throughout the semester.

9 CONCLUSION

Through the National Science Foundation, team Easel 5000 was given the opportunity to build an adjustable easel that will be used in an art studio specifically for people with disabilities. In particular, this project was built for a man named Tom Depugh. The easel project was done to redesign an easel that was previously built but was not appropriate for the artist. The features of the easel include adjustability; a battery powered lighting system, and the ability to attach to a wheel chair tray. Numerous design options were made for the easel from which an optimal was chosen. The construction for the design was planned out and was executed in the second part of the course. This involved trouble shooting, redesigning, construction and teamwork. Ultimately, the finished easel will be used in the Passion Works Studio and hopefully will be used by Tom in the rest of his future painting endeavors.

9.1 Closing Remarks

We wish the best of luck to the artist and assistant. Much time and energy went into the development and construction of this easel and we know it will help. Please do not hesitate to contact us in the future if we can be of any assistance!

-Team 3

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12 APPENDIX

12.1 Updated Specifications

Introduction and Overview

Through the National Science Foundation, the Biomedical Engineering Senior Design has been given the opportunity to build an adjustable easel that will be used in an art studio specifically for an artist with cerebral palsy. The easel project has been done previously, but was not appropriate for the artist, hence Team 3 will be designing and building an easel suited for his use. The easel itself will have the ability to tilt forward and backward, be brought toward the artist, have a lighting system, and attach and detach from a wheelchair tray. Ultimately, this easel will be used in the Passion Works Studio and will hopefully be very helpful for the artist.

Technical Specifications

Environmental

Space and Dimensional Considerations

Size	Ability to be fastened on a wheelchair tray
Weight	Light enough to be moved by an aid
Location	Used in the middle of a busy art room

Electrical

Lighting

Power Supply	Cordless Battery operated
Illumination	Able to illuminate a canvas
On/Off Switch	Easily operated

Mechanical

Structural Considerations

Stability	Sturdy when attached to a table top
Moveable Joints	Pivoting joints Ability to tilt and project toward the artist
Lockable Positions	To hold canvas in place To remain immobile during artist use
Canvas size	Ability to hold canvases ranging from 8”x8” to 20”x20”

Economical

Budget

Maximum	$750